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CONSEIL GÉNÉRAL DES PÊCHES POUR LA MÉDITERRANÉE

GENERAL FISHERIES COUNCIL FOR THE MEDITERRANEAN

Rapport de la première session

DU GROUPE DE TRAVAIL SUR LES RÉCIFS ARTIFICIELS ET LA MARICULTURE

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Ancône, Italie, 27-30 novembre 1989

Report of the first session of

THE WORKING GROUP ON ARTIFICIAL REEFS AND MARICULTURE

Ancona, Italy, 27-30 November 1989

ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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CONSEIL GENERAL DES PECHES POUR LA MEDITERRANEE

GENERAL FISHERIES COUNCIL FOR THE MEDITERRANEAN

RAPPORT DE LA PREMIERE SESSION DU GROUPE DE TRAVAIL SUR LES RECIFS ARTIFICIELS ET LA MARICULTURE

Ancône, Italie, 27-30 novembre 1989

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ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE
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Rome 1990

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PREPARATION DE CE DOCUMENT

Le présent texte constitue la version définitive du Rapport de la première session du Groupe de travail du Conseil général des pêches pour la Méditerranée (CGPM) sur les récifs artificiels et la mariculture. Elle est diffusée en français et anglais, en ce qui concerne le texte et l'annexe A, et en version originale pour les annexes B, C et D. Les références bibliographiques accompagnant chaque document dans l'Annexe D sont reproduites telles qu'elles ont été données par les auteurs respectifs.

PREPARATION OF THIS DOCUMENT

The present text constitutes the final version of the Report of the First Session of the General Fisheries Council for the Mediterranean (GFCM) Working Group on Artificial Reefs and Mariculture. It is published in French and English, in respect of the text and Appendix A, and in the original language, in respect of Appendixes B, C and D. The bibliographic references in the papers in Appendix D are as submitted by the respective authors.

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RESUME

Le Groupe de travail a fait le point sur la théorie, puis l'étude et mise en oeuvre des récifs artificiels et la mariculture s'y rapportant dans le bassin méditerranéen, ainsi que l'évolution de ce genre de structures au Japon, aux Etats-Unis et ailleurs. Il a ensuite étudié les autres aspects et problèmes dans les domaines de l'écologie, la biologie, la technologie, l'halieutique, économiques et sociaux, administratifs et juridiques. Enfin, il a proposé des programmes scientifiques d'accompagnement et passé en revue les perspectives de la mise en oeuvre de ces structures.

ABSTRACT

The Working Group reviewed the theory, design and exploitation of artificial reefs and associated mariculture in the Mediterranean basin, as well as the evolution of this type of structure in Japan, the USA and elsewhere. It then considered other aspects and problems in the fields of ecology, biology, technology, fisheries, socio-economics, administration and legislation. It also proposed some required research programmes and reviewed the prospects for the exploitation of such structures.

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A Ordre du jour/Agenda

B Liste des participants/List of Participants

C Discours d'introduction par le Prof. François Doumenge (Monaco)/Keynote Speech by Prof. François Doumenge (Monaco)

D Contributions scientifiques données pendant la Session/ Scientific Papers Delivered During the Session

OUVERTURE

1. Le Groupe de travail du Conseil général des pêches pour la Méditerranée (CGPM) sur les récifs artificiels et la mariculture a tenu sa première session du 27 au 30 novembre 1989 dans les locaux de la Foire d'Ancône à l'aimable invitation du Gouvernement italien et de la Région des Marches et avec la collaboration active du Directeur et du personnel de l'Institut hôte, l'Istituto di Ricerche sulla Pesca Marittima (IRPeM), (CNR) Consiglio Nazionale delle Ricerche, d'Ancône.

2. Le Directeur, M. Giovanni Bombace, a d'abord invité M. Giuseppe Maggio-Aprile, représentant le Ministère de la Marine marchande (Direction générale des pêches), à prendre la parole.

3. Monsieur Maggio-Aprile a souligné l'importance des récifs artificiels non seulement pour l'Italie, mais aussi pour les autres Etats membres du CGPM. La création de récifs artificiels et autres installations de mariculture ouvre, à son avis, de nouvelles perspectives en matière de développement et d'aménagement moderne des pêches. La première session du Groupe de travail devrait donc, selon lui, être une excellente occasion d'échanger des données d'expérience, positives ou non, entre les Etats membres intéressés du CGPM et leurs institutions compétentes. Elle pourrait aussi apporter aux Etats membres les éléments nécessaires à une action ultérieure et adresser un message encourageant aux responsables des politiques et autres décideurs. M. Maggio-Aprile a, au nom de son Ministère, rendu particulièrement hommage aux efforts exercés par la Région des Marches, ainsi que par M. Bombace et ses collaborateurs de l'IRPeM pour développer cette activité en Italie d'une manière générale et plus particulièrement dans la région Adriatique.

4. Monsieur Marco Bellardi, parlant au nom du Conseiller pour la pêche de la Région des Marches, a exprimé l'intérêt de la Région pour les travaux consacrés par M. Bombace et ses collaborateurs à l'étude et à l'expérimentation des récifs artificiels dans la partie centrale de la mer Adriatique. Il a dit qu'il voyait dans les récifs artificiels un outil potentiellement important d'aménagement et de développement des pêches. Dans ce contexte, les récifs artificiels et la mariculture aideront à stabiliser le marché du poisson, favoriseront le développement de la pêche sportive littorale et faciliteront, pour les pêcheurs, le passage d'une activité artisanale en déclin à une pêche fondée sur les récifs artificiels et la mariculture, qui sont aussi un moyen de reconstituer certains stocks de poissons lourdement exploités. Enfin, M. Bellardi a souligné l'intérêt que porte la Région des Marches à la coopération qui pourrait s'instaurer entre les Etats membres du CGPM pour faire progresser cette forme relativement nouvelle de développement et d'aménagement des pêches.

5. Le Maire d'Ancône, M. Franco del Mastro, a souhaité aux participants la bienvenue dans sa ville dont il a rappelé la longue tradition et qui, avec son port de commerce et de pêche, est à l'origine du développement socio-économique de la Région. M. del Mastro s'est chaudement félicité de l'initiative prise par le CGPM et l'IRPeM de créer et de lancer le Groupe de travail. Selon lui, le développement des récifs artificiels est un moyen de développer la pêche artisanale et, par là, de mieux protéger la zone côtière, de promouvoir la reconstitution de ressources surexploitées et de développer un jour la mariculture dans les eaux du large. Grâce à la reconversion des pêcheurs, cette initiative devrait aussi permettre de résorber une partie de la capacité excédentaire du petit chalutage de la région. Il a reconnu qu'il reste encore de nombreux problèmes à résoudre - de caractère administratif,

juridique et d'aménagement, entre autres - et que le Groupe de travail aurait, par ses avis et ses indications, un rôle important à jouer dans ce domaine, tout cela supposant, a-t-il dit, un lien étroit entre la recherche et le développement économique. Le Maire a invité les participants à visiter sa ville, dotée d'un riche patrimoine artistique et historique.

6. Le Secrétaire du Conseil, M. Ray C. Griffiths, a remercié les autorités italiennes d'avoir rendue possible la tenue de cette première session à Ancône; il a remercié le Ministère de la marine marchande, la Région des Marches, le Maire d'Ancône, le Conseil national de la recherche et l'Institut de recherche sur les pêches maritimes, et tout particulièrement M. Bombace et ses collaborateurs pour leur accueil chaleureux et leur assistance.

7. Monsieur Bombace a rappelé que le sujet des récifs artificiels et de la conchyliculture suspendue en Méditerranée a été traité trois fois dans le cadre de réunions internationales: (i) à l'occasion du Symposium sur l'aménagement des ressources vivantes en Méditerranée, tenu à Palma de Majorque en 1980; (ii) dans le cadre des Journées d'études organisées par la CIESM à Cannes en 1982 pour examiner les aspects scientifiques des récifs artificiels et de la mariculture suspendue (et dont les Actes ont été publiés en 1983); et (iii) dans le cadre d'une Consultation technique du CGPM sur la conchyliculture en mer et les récifs artificiels qui s'est tenue à Ancône en 1986 et dont le rapport a été publié dans le Rapport FAO sur les pêches No. 357.

8. Le Groupe de travail a particulièrement regretté qu'aucun représentant de la France et de la Bulgarie ne participe à cette première session du Groupe de travail, d'autant que des experts de ces deux pays avaient apporté une importante contribution à la Consultation technique susmentionnée.

9. Plusieurs réunions nationales ont également été organisées, notamment en Italie, pour traiter des récifs artificiels et de la mariculture et, au cours de ces dix dernières années, de nombreuses zones récifales ont été installées en Méditerranée. La question a donc pris de l'importance. De nouvelles possibilités s'ouvrent aujourd'hui à la pêche côtière, ce qui appelle une attention accrue de la part des législateurs et des administrateurs des pêches. M. Bombace a rappelé que c'est pour ces raisons que le CGPM, à sa dix-neuvième session tenue à Livourne en mars 1989, a décidé de créer un Groupe de travail qui serait spécifiquement chargé de traiter de cette question. La décision, a-t-il souligné, a été prise à l'unanimité par tous les Etats membres présents. Il a informé le Groupe de travail que la Società Italiana di Biologia Marina avait créé un comité des récifs artificiels.

10. Monsieur Bombace a ensuite lu le mandat du Groupe de travail pour servir d'indication au déroulement des travaux de la présente session. Il a insisté sur le fait que le Groupe de travail s'est vu confier une lourde responsabilité, à savoir étudier et évaluer les principaux aspects de la création de récifs artificiels et d'installations maricoles afin de dégager, en tenant compte de l'expérience acquise ailleurs dans le monde, des approches utiles. C'est pourquoi il s'est déclaré perplexe au sujet des réserves, principalement d'ordre intellectuel, qui se manifestent encore à l'égard des récifs artificiels et que ne semblent pas partager les pêcheurs, les administrateurs et les politiciens. Il a donc exprimé l'espoir que le Groupe de travail contribuerait à dissiper ces réserves.

11. Monsieur Bombace a ensuite invité M. François Doumenge, Directeur du Musée océanographique de Monaco et Secrétaire général de la Commission internationale pour l'exploration scientifique de la mer Méditerranée (CIESM), à prononcer l'exposé d'introduction de la session.

12. Monsieur Doumenge a passé en revue, de façon assez détaillée, les dernières nouveautés en matière de récifs artificiels et de mariculture, et en particulier les développements enregistrés récemment au Japon et aux Etats-Unis. Son exposé d'introduction est intégralement reproduit à l'annexe D.

ADOPTION DE L'ORDRE DU JOUR

13. Le Groupe de travail a adopté l'ordre du jour, qui est joint en annexe A.

ELECTION DU PRESIDENT ET DU VICE-PRESIDENT

14. Monsieur Abdelkadous Morchid (Maroc) a proposé d'élire M. Giovanni Bombace (Italie) au poste de Président du Groupe de travail. Cette proposition a été appuyée par M. Lopez Garcia (Espagne). M. Bombace a été élu à l'unanimité.

15. Monsieur Maggio-Aprile (Italie) a proposé d'élire M. Youssef Ouati (Maroc) au poste de Vice-président. Cette proposition a été appuyée par M. Bounouni (Algérie). M. Ouati a été élu à l'unanimité.

ORGANISATION DE LA SESSION, CALENDRIER ET DOCUMENTATION

16. Le Secrétaire a fourni des indications concernant l'organisation de la session et en particulier la possibilité, si nécessaire, de former pour la session des groupes de travail ou de rédaction chargés de questions particulières et la préparation au jour le jour du projet de rapport succinct de façon à faciliter son adoption. Il a brièvement décrit la documentation proposée.

17. Une question de terminologie (définition des termes "récifs artificiels" et "mariculture") a été soulevée, mais est traitée dans les paragraphes 28 à 39 du présent rapport.

18. La liste des participants figure à l'annexe B.

THEORIE DES RECIFS ARTIFICIELS ET DES INSTALLATIONS DE MARICULTURE

19. Le Président a introduit ce point de l'ordre du jour. Il est d'abord revenu sur l'objection formulée, surtout d'un point de vue théorique, par certains chercheurs à l'encontre des récifs artificiels. Cette objection se résume essentiellement à ceci: les récifs artificiels ne créent pas une nouvelle biomasse; ce sont simplement des dispositifs qui attirent et concentrent la biomasse existant déjà dans une zone déterminée. L'argument concerne surtout les poissons. Si l'on prend, par exemple, une pêcherie dans laquelle les poissons et les organismes visés par la pêche sont distribués d'une certaine manière dans l'espace, la création de récifs artificiels n'entraînera, sous l'effet de la force d'attraction (du récif) appelée "thygmotropisme", qu'une agrégation d'espèces à l'intérieur d'un rayon donné.

20. Pour répondre à cette objection, il faut se reporter aux deux principaux paramètres des stocks, qui sont la mortalité et la croissance. Si les récifs artificiels ont la possibilité, pour l'espèce recherchée, de modifier de quelque façon les courbes mortalité-temps et croissance-temps, il en résultera une modification de la courbe de la biomasse du stock, car celle-ci est le produit des deux courbes susmentionnées.

21. Il ne fait pas de doute que la mise en place de substrats artificiels, la création d'habitats de types divers et l'installation de structures cavitaires

contribuent à protéger les juvéniles des espèces attirées par un récif artificiel. Les chercheurs qui étudient les récifs artificiels, et les pêcheurs qui capturent des poissons adultes ou juvéniles à proximité de récifs artificiels, savent que la structure cavitaire des récifs a certainement pour effet de protéger les jeunes. Cette protection, qui se traduit par une survie accrue durant la phase de pré-recrutement, atténue forcément la pente de la courbe de mortalité, ce qui signifie que la biomasse du stock adulte augmente. Cette relation est cependant difficile à démontrer scientifiquement. Nous opérons en effet à l'intérieur d'un système ouvert, qui est le lieu d'un échange d'énergie entre la structure récifale et l'espace environnant.

22. Il faut poursuivre les recherches en vue d'obtenir les données qualitatives et quantitatives nécessaires pour mettre en évidence la réelle diminution de la mortalité au niveau du systéme récifal (la question des recherches complémentaires est traitée plus amplement dans les paragraphes 92 à 94 ci-après).

23. Les organismes sessiles comestibles (par exemple les bivalves sestonophages comme les moules, les huîtres, etc.) qui font l'objet d'une récolte par l'homme ne posent pas de gros problèmes.

24. En effet, les supports solides utilisés à leur propos, qu'il s'agisse de câbles ou de cordages suspendus, de structures en béton ou autres matériaux, compensent le facteur limitant qui est, pour ce qui concerne les organismes sessiles, la surface disponible pour l'installation des larves. Le développement des jeunes et la croissance de la biomasse dépendent de la richesse du milieu en termes de production primaire, secondaire ou paraprimaire (matières organiques en suspension).

25. Quant à la question de savoir si la structure récifale favorise la croissance des organismes marins vagiles qui vivent à l'intérieur ou au voisinage du récif, on peut avancer l'argument suivant: la nouvelle surface disponible pour la colonisation, les structures cavitaires, les diverses stratégies d'implantation adoptées par les organismes sessiles et la diversité des habitats suscitent l'établissement de nouveaux réseaux trophiques de type différent. La question qui se pose est la suivante: est-ce que ces nouveaux réseaux, en augmentant la quantité de nourriture disponible, influent sur la croissance des espèces récifales? Là aussi, la réponse est probablement affirmative, encore faut-il l'appuyer par des données scientifiques.

26. Pour répondre à cette question, les chercheurs devront concevoir des modalités d'expérimentation. Pour le moment, nous pouvons observer des juvéniles nageant autour des récifs, des poissons se nourrissant de proies qu'ils trouvent dans les cavités et les interstices; nous voyons des poissons qui, grâce à leur thygmotropisme, ont la possibilité de se nourrir, au voisinage ou à l'intérieur du récif artificiel, des proies qu'ils préfèrent. L'observation directe et, plus encore, l'analyse des contenus stomacaux peuvent appuyer cette thèse mais il faut la démontrer au moyen de données quantitatives et de recherches expérimentales. L'observation directe à elle seule ne suffit pas.

27. Il importe aussi de déterminer dans quelle mesure un récif artificiel ou un système récifal peut influer d'une part sur la courbe de croissance (poids-temps, poids-âge) du poisson lui-même, et d'autre part sur l'abondance réelle (nombre de poissons) d'une espèce donnée, car ces deux facteurs, dont l'importance relative peut dépendre de l'espèce visée, conditionnent la biomasse du stock.

Définition

28. Pour donner une définition des récifs artificiels, on peut dire qu'ils sont de trois types principaux décrits sommairement aux paragraphes 29 à 31; en outre, les substrats, les modules, les matériaux et les structures utilisés, de même que la densité des récifs dans l'espace, obéissent à certaines stratégies.

29. On peut avoir par exemple des récifs qui ont uniquement pour but d'empêcher le chalutage illégal; ce sont des obstacles mécaniques placés sur le fond de la zone, particulièrement de la zone littorale, que l'on entend protéger contre les chalutiers. Ces obstacles ont un effet biologique en ce qu'ils contribuent à accroître la taille et le poids des jeunes poissons vivant près du fond originel et qui, sans cela, auraient été capturés par le chalutage illégal.

30. Il y a aussi des récifs qui, de par la structure des modules employés, la stratégie suivie et les possibilités qu'ils offrent pour la conchyliculture, peuvent être classés dans la catégorie des récifs artificiels polyvalents. C'est le cas généralement des récifs qui ont été mis en place dans l'Adriatique par l'Istituto di Richerche sulla Pesca Marittima (IRPeM).

31. Enfin, il y a des récifs spécialisés, constitués d'un type de module particulier, qui ont pour but de favoriser une espèce déterminée ou d'engendrer des changements dans certains paramètres de l'environnement.

32. En ce qui concerne la conchyliculture suspendue, l'installation est plus ou moins toujours la même. Elle se compose de supports solides posés sur le fond, de bouées accrochées à des câbles terminaux et de lignes horizontales d'où pendent des cordages sur lesquels les larves viendront se fixer ou des boudins sont attachés pour l'accroissement du naissain. Des flotteurs plus petits sont fixés sur chaque ligne pour diminuer la tension provoquée par le poids des moules.

33. Dans certains pays, des structures (câbles, cordages, lignes en plastique, pneus de voitures reliés entre eux, etc.) sont fixées au fond d'un côté et flottent librement à l'autre extrémité. Ce genre de dispositif est généralement appelé FAD ("Fish Attracting Devices").

34. Monsieur Bombace a demandé s'il existe un lien entre ces différents types de structures et s'il serait possible de donner une même définition pour tous ces exemples, car les récifs artificiels sont aussi, sans aucun doute, des FAD, c'est-à-dire un moyen d'attirer et de concentrer divers genres d'organismes marins. Les récifs artificiels, les FAD, ou toute autre méthode d'agrégation, y compris les installations conchylicoles, ont le même objectif: accroître la productivité halieutique du milieu.

35. En ce qui concerne une définition générale, il a été suggéré que les récifs artificiels, les systèmes d'attraction et d'agrégation d'organismes marins et les installations de mariculture suspendue, sont des structures qui: sont mises en place par l'homme sur le fond marin, ou même en contact partiel avec le fond, et, éventuellement, peuvent s'élever jusqu'à la couche supérieure de l'eau au moyen de systèmes de suspension; utilisent des technologies simples et des stratégies et mécanismes bio-écologiques; et visent à accroître la production halieutique du milieu et/ou à conserver certaines zones du fond marin.

36. Monsieur Lopez García (Espagne) a cependant fait observer que, en Espagne, mais aussi dans la CEE, on fait une distinction entre les récifs artificiels et la mariculture (au sens de production industrielle de poissons ou de mollusques en mer) et a estimé que cette dernière activité n'est pas de la compétence du Groupe de travail. Il a mis en doute la possibilité de faire entrer les plate-formes pétrolières, par exemple, dans la définition proposée. Selon lui, les récifs artificiels sont plus destinés à protéger les stocks de poissons et de mollusques ainsi que l'environnement marin littoral, qu'à produire des quantités industrielles de poissons ou de mollusques.

37. Monsieur Bombace a signalé que les récifs artificiels, en protégeant les fonds de pêche, augmentent la production de poisson et qu'il n'est pas possible de faire une distinction précise entre quantités industrielles et non industrielles, comme l'a jusqu'ici montré l'expérience japonaise.

38. Monsieur John Caddy a fait observer que, de toute manière, les récifs artificiels et les installations de mariculture, quel que soit leur caractère, ne peuvent être étudiés de façon rationnelle que dans le contexte de l'aménagement des zones côtières (cette question est reprise plus en détail dans les paragraphes 58 et 59, ci-après).

39. Sur ce point, M. Lopez García (Espagne) a signalé que les installations de mariculture ont des objectifs et des techniques différents et ne doivent pas être simplement considérés comme un facteur supplémentaire du point de vue de l'aménagement côtier.

Ecologie

40. Monsieur Bombace, en introduisant ce point de l'ordre du jour, a posé une question d'ordre général mais importante qui a aussi un lien avec le point 5.3 (Effets bio-écologiques et halieutiques) de l'ordre du jour: comment se produit cette augmentation de la production halieutique? Il a proposé un certain nombre de réponses pouvant servir de base de discussion pour l'examen des points 5.2 et 5.3 de l'ordre du jour:

(i) Par recyclage énergétique (fixation de larves d'organismes sestonophages tels que les bivalves utilisés par l'homme, moules, huîtres, etc.).

(ii) Par réduction de la mortalité des larves et des juvéniles. Cette réduction s'obtient de différentes manières et est fonction des exigences et nécessités éco-physiologiques des différents groupes d'animaux. Par exemple, pour les invertébrés sessiles, les larves ont besoin pour se fixer d'un support quelconque (surface plane, câbles, etc.). Pour les formes vagiles, et notamment pour les poissons nectobenthiques, il faut des cavités ouvertes, offrant aux juvéniles des lieux où se cacher ou des possibilités de camouflage. Pour les formes benthiques sédentaires, des cavités fermées sont acceptables tandis que pour les gros décapodes, il faut une série de cavités de grandeur croissante pouvant offrir un refuge à des animaux qui viennent de muer et dont la taille augmente.

(iii) Par attraction et concentration d'organismes. Divers types et systèmes d'attraction et de concentration peuvent être utilisés (appâts divers, lumière, petites bulles d'air comprimé, mais aussi des corps flottants tels que les "Kannizzati" utilisés dans le sud de l'Italie et à Malte pour la pêche à l'ombre ou des corps flottant à proximité de la surface, etc.). L'effet est aisément observable

chez certaines espèces pélagiques. Même quand la source d'attraction n'est pas constituée par des appâts-nourriture, les poissons viennent au récif dans l'espoir d'y trouver une proie. Le terme technique est thygmotropisme (ou même thygmotactisme), mais nous ne comprenons pas encore très bien le mécanisme qu'il recouvre; peut-être s'agit-il simplement de trophisme.

(iv) Par création de nouveaux réseaux alimentaires résultant de l'aménagement de nouveaux espaces, habitats et schémas de colonisation. Plusieurs espèces d'invertébrés ou d'organismes végétaux peuvent satisfaire leurs besoins écologiques grâce à ces nouveaux réseaux alimentaires, ce qui donne lieu à une diversification qualitative de la nourriture disponible pour le niveau trophique tertiaire.

(v) Par protection du fond marin ou, pour mieux dire, de la faune originelle des fonds sableux-vaseux sur lesquels ont été placés les obstacles formant récifs. Le chalutage illégal devient impossible, ce qui permet un accroissement en taille et en poids des individus (et éventuellement de leur nombre), donc une augmentation de la biomasse exploitable.

41. Madame Isabel Moreno (Espagne) a fait observer que tous les récifs artificiels n'entraînent pas, comme on pourrait le penser, une diversification de la faune de la zone dans laquelle ils sont installés, surtout s'ils sont conçus pour augmenter l'abondance de la biomasse d'une espèce particulière.

42. Monsieur Abdelkadous Morchid (Maroc) a insisté sur le fait qu'il importe de déterminer le flux d'énergie entre les organismes sessiles et vagiles, ainsi que la relation entre un récif (ou une zone récifale) et l'espace environnant.

43. Pour M. Doumenge (Monaco), le problème est particulièrement crucial en ce qui concerne les espèces pélagiques et il est nécessaire d'entreprendre des études de longue durée portant sur une zone étendue autour du récif (ou système récifal). Il a signalé que le comportement du listao (Katsuwonus pelamis), qu'on a pu étudier pendant cinq ans autour des FAD disposés entre les îles de Tahiti et Mooréa en Polynésie française, diffère considérablement selon la saison et selon le moment de la journée (agrégation pendant la nuit, peut-être pour des raisons de sécurité, et dispersion pendant la journée, pour s'alimenter). Ce type de comportement chez une espèce donnée doit être étudié si l'on veut utiliser les récifs artificiels pour favoriser la production de telle ou telle espèce.

44. En ce qui concerne l'évaluation des effets des récifs artificiels et des installations de mariculture sur l'écologie du voisinage, M. Bombace a suggéré que l'on étudie les contenus stomacaux des poissons prédateurs et que l'on fasse des enquêtes sur les oeufs et les larves dans les zones concernées.

Effets bio-écologiques et halieutiques

45. En ce qui concerne tout d'abord les effets bio-écologiques, on notera que la création d'un récif artificiel (ou d'un système récifal) est immédiatement suivie par la colonisation des surfaces puis, plus lentement peut-être, par l'occupation des cavités et des habitats compris dans la structure ou entre les modules qui la composent. Toutefois, cette colonisation (des surfaces ou des cavités) peut varier en fonction de facteurs tels que la latitude (même dans les limites de la Méditerranée); la longitude (par exemple entre le côté

occidental et oriental d'une importante masse continentale telle que l'Italie); l'époque de l'année choisie pour l'installation du récif; le matériau dont est composé le récif; la conformation détaillée des modules (nombre et variété de cavités et de niches, etc.); la profondeur des plans du récif par rapport à la surface de la mer (effet éventuel de la lumière); la relation qui existe entre l'emplacement du récif artificiel ou de l'installation de mariculture et des effluents industriels et fluviaux ou d'autres grands éléments hydrographiques; l'abondance relative, au moment de l'installation du récif artificiel ou de l'installation maricole, de larves d'espèces qui deviendront sessiles au stade adulte; les grands courants et les courants de moindre importance au voisinage et à proximité immédiate du récif artificiel; l'état trophique (eutrophique, oligotrophique, etc.) du milieu où se trouve le récif artificiel ou l'installation de mariculture.

46. La colonisation n'entraîne pas nécessairement l'installation d'une communauté climacique (stable), qu'elle soit sessile ou vagile ou mixte (c'est-à-dire comprenant les deux principaux composants d'une communauté récifale). Il semble qu'intervienne une sorte de processus aléatoire, avec peut-être la médiation de messagers chimiques qui ont pour rôle de favoriser la colonisation du récif par une espèce particulière une fois que la "masse critique" s'est mise en place, cette population pionnière attirant éventuellement à son tour d'autres colons. Il y a peut-être aussi un effet de seuil, en vertu duquel le volume du récif artificiel lui-meme, détermine une séquence ou un type particulier de colonisation dans un ensemble donné de conditions d'environnement.

47. Monsieur Giulio Relini (Italie) a présenté une étude de la colonisation d'un récif artificiel créé à Loano, en employant des panneaux de fibrociment. La séquence a été tout-à-fait différente de celle qui a été observée dans le cas du système récifal installé près d'Ancône; il n'y a eu notamment pas de prédominance climacique de la moule commune (Mytilus galloprovincialis). Différentes orientations des panneaux n'ont pas produit de colonisations sensiblement différentes par des organismes sessiles. On a noté une tendance à la prédominance, dans certains cas, de bryozoaires dans la colonie et d'ascidiens dans d'autres cas, généralement liée à la profondeur des panneaux par rapport à la surface de la mer (et donc de différences d'illumination et de température). Un résultat surprenant a été observé à propos des oursins de mer, qui ont complètement nettoyé les surfaces sur lesquelles ils vivaient et préparé ainsi la voie à une nouvelle période de colonisation.

48. La communication de M. Relini est reproduite dans l'annexe E, qui comprend aussi d'autres contributions scientifiques présentées à divers moments de la session.

49. Monsieur G.D. Ardizzone (Italie) a rendu compte des résultats d'une étude de la colonisation d'un récif artificiel expérimental créé il y a huit ans au large de Fregene, à quelque six kilomètres de l'embouchure du Tibre. La mer Tyrrhénienne est généralement oligotrophe, mais la proximité du Tibre joue probablement un rôle important. En bref, l'étude a montré que, si les moules sont devenues l'espèce dominante, il ne s'est jamais établi de communauté climacique (stable); la prédominance initiale d'hydroides est considérée comme vitale pour la colonisation ultérieure par les moules. On pense que ce sont principalement des épisodes de sédimentation qui empêchent l'installation d'une population dominante de moules. Celles-ci sont périodiquement remplacées par des détritivores. La sédimentation, la productivité localement forte de la mer (autour de Fregene) et les effluents transportés par le fleuve sont des forces antagonistes. La communication de M. Ardizzone est reproduite à l'annexe E.

50. Selon M. Bombace, il se pourrait que la récolte périodique des moules et autres formes d'intervention humaine soient nécessaires pour empêcher la colonisation cyclique et, par conséquent établir une communauté climacique principalement constituée de moules.

51. Monsieur Morchid (Maroc) a fortement appuyé cette opinion et a noté que le vieillissement des moules les rend difficilement comestibles par les poissons.

52. Monsieur Silvano Riggio (Italie) a confirmé que, dans la région sicilienne et dans le golfe de Gênes, plusieurs des facteurs signalés au début de la présente section ont été amplement confirmés par des études effectuées sur des récifs artificiels dans ces deux zones. Il a fait remarquer que, si les résultats obtenus autour de la Sicile et dans le golfe de Gênes sont analogues, ils sont très différents de ceux qu'a obtenus Ardizzone au large de Fregene et dans le golfe de Naples. Il a souligné l'importance d'une structure tridimensionnelle dans le système de colonisation et a en conséquence mis en garde contre l'interprétation des résultats d'études basées essentiellement sur des panneaux à deux dimensions. Il a insisté aussi sur l'importance du matériau utilisé pour la construction des récifs artificiels, les matériaux calcaires étant en général meilleurs, pour ce qui est de la colonisation, aux matériaux à base de silicates minéraux. M. Riggio a estimé aussi que le rendement biologique global d'un récif artificiel atteint généralement un maximum, après quoi il fléchit. Un autre rôle important des récifs artificiels consiste aussi, à son avis, à faciliter l'élaboration d'un modèle écologique pour les zones côtières.

53. Monsieur Doumenge (Monaco) a souligné qu'il est important de forcer divers processus si l'on veut obtenir des récifs artificiels et des installations de mariculture les effets souhaités. Il a cité, à titre d'exemples, l'emploi d'"algues plastiques" pour favoriser la fixation, et l'emploi d'aliments artificiels (comme les effluents des installations de traitement des eaux usées, les déchets de l'aquaculture) pour engendrer un écosystème récifal dynamique; le choix des facteurs de forçage doit être cependant fait avec beaucoup de soin et être préalablement étudié. On peut aussi modifier le milieu en provoquant de mini-upwellings ou en créant des courants circulaires ou par introduction de sujets de repeuplement.

54. Monsieur Relini (Italie) a souligné le caractère changeant du thygmotropisme; on a d'abord l'existence du récif artificiel lui-même, puis la colonisation; puis, en règle générale, la création d'une communauté climacique; enfin les fluctuations normales de la communauté climacique. Chaque phase exerce une attraction de type différent pour les poissons et les mollusques thygmotropiquement motivés. Un aspect important du forçage consiste donc dans la grande diversité des micro-niches du système récifal.

55. En ce qui concerne les effets sur la pêche, la création de récifs artificiels et d'installations de mariculture (RAIM) tend, comme on l'a déjà noté, à accroître la taille moyenne des poissons se trouvant dans la zone de construction. M. Doumenge a expliqué que, pour certaines espèces très prisées (comme les sparidés), les RAIM favorisent la stabilité des stocks, d'autant que certaines espèces de sparidés changent de sexe une fois au moins dans leur vie; ce changement est souvent un effet de l'abondance du stock. Il a suggéré aussi que les récifs artificiels, pour donner de bons résultats, doivent peut-être dépasser un volume seuil (par exemple 50 000 mètres cubes) sans pour autant dépasser un volume maximum limitant (80 000 mètres cubes). Il est nécessaire de calculer ces valeurs, au moins empiriquement; pourtant, jusqu'à présent, du moins pour ce qui concerne la Méditerranée, les études

sont encore en grande partie conditionnées non pas par une politique rationnelle de mise en valeur des zones côtières, comme au Japon, mais par les crédits, les installations et les conditions de recherche des institutions concernées. De plus, il est peu probable que l'on puisse obtenir un effet sérieux sur la pêche sans un programme massif de repeuplement, ce qui exige aussi des écloseries. Il a estimé que l'élevage en cages, comme les cultures suspendues sous radeaux ou sur palangres, correspond à une forme de récif artificiel pouvant avoir un véritable effet sur la pêche aussi bien positif (protection des juvéniles, apports de nourriture) que négatif (pollution des fonds, eutrophisation, dissemination des pathologies, etc.).

56. Monsieur Lopez García (Espagne) a informé le Groupe de travail que les résultats enregistrés jusqu'ici dans son pays avec les récifs artificiels sont généralement semblables à ceux qui ont été obtenus en Italie.

57. Monsieur Caddy a rappelé au Groupe de travail que le CGPM s'efforce, depuis de nombreuses années (dans le cadre de ses consultations techniques sous-régionales, par exemple), de susciter des "effets sur la pêche" par beaucoup d'autres solutions, par exemple en encourageant l'institution de périodes de fermeture, de zones de fermeture, l'augmentation du maillage minimum, etc. Les RAIM sont simplement un autre moyen d'améliorer les pêcheries de la région du CGPM. L'on ne sait pas encore lesquelles de ces solutions, et combinaisons de solutions, se révèleront les meilleures. Il serait donc hasardeux de se montrer dogmatique au sujet du rôle des récifs artificiels ou de la mariculture, employés isolément ou en combinaison.

Rapports entre le milieu, les récifs artificiels et les installations de mariculture

58. En introduisant ce point (5.4) de l'ordre du jour, le Président a remarqué que la question des rapports entre les récifs artificiels et leur milieu environnant est extrêmement intéressante et peut amener à penser qu'il existe une sorte de déterminisme qui régit l'installation des organismes sessiles et vagiles.

59. Le Groupe de travail s'est penché sur quelques exemples, dont certains avaient déjà été évoqués durant l'examen des points 5.2 et 5.3 de l'ordre du jour. Ces exemples peuvent être résumés comme suit:

(i) Les mêmes modules, les mêmes structures immergées dans des milieux différents donnent des réponses bio-écologiques différentes. La colonisation de substrats artificiels et la succession des espèces diffèrent selon qu'il s'agit de récifs installés dans des eaux riches (où les particules de matière organique, de phyto- et de zooplancton abondent) ou dans des eaux pauvres (oligotrophes). Les récifs artificiels installés dans l'Adriatique ou au nord de la Sicile sont tous construits en blocs de béton et en forme de pyramide. Dans l'Adriatique, après une phase de colonisation très rapide par des hydroïdes, des bryozoaires, des tuniciers et quelques éponges, on passe à une installation prédominante de bivalves sestonophages représentés principalement par des moules et des huîtres. Le phytobenthos se limite à la présence sporadique de quelques algues nitrophiles (ulvacés). Cette communauté climacique peut être réalisée en l'espace de deux ans. La chaîne alimentaire est simple: production primaire et para-primaire (particules organiques en suspension) - bivalves filtreurs - invertébrés intersticiels ou naissain de bivalves - poissons carnivores. Le

deuxième maillon de cette chaîne (les bivalves) est déjà exploitable. Dans les eaux les plus méridionales et oligotrophes, qui sont parfois riches en matériaux particulaires et en organismes planctoniques de très petites dimensions (picoplancton), l'évolution biologique des substrats est très différente. Les bryozoaires encroûtants et arborescents, les hydroïdes, les tuniciers et les éponges constituent une phase de longue durée. Les espèces intersticielles sont présentes, le réseau trophique est plus complexe, le phytobenthos est mieux représenté et plus diversifié, et plusieurs espèces de poissons et de macro-invertébrés ayant une importance économique vivent dans les récifs ou aux alentours.

(ii) Les différents étages de l'édifice récifal sont occupés par les diverses espèces de poissons (voir la commmunication de G. Bombace intitulée "Les poissons récifaux", reproduite à l'annexe E).

(iii) Les mêmes types de récifs installés dans le même milieu mais à des saisons différentes auront une colonisation initiale différente. En Moyenne Adriatique, une immersion printannière est très favorable à l'installation d'hydroïdes, qui préparent le terrain pour les larves de moules. Par contre, une immersion automnale favorise l'installation de larves d'ascidies (Ciona intestinalis, par exemple) qui deviennent prédominantes; même si en fin de compte ce sont les moules qui prédominent, cette prédominance ne s'impose qu'au printemps suivant, de sorte que pour la récolte, on aura perdu entre cinq et six mois.

(iv) Dans les mers où, pendant l'hiver, on a une inversion thermique entre la surface (5-6°C) et le fond (12-13°C), et surtout entre les eaux littorales et les eaux du large, comme c'est le cas en Moyenne et Haute Adriatique, on assiste à une migration de la plupart des espèces de la côte vers les eaux plus profondes du large; il semble probable que même les espèces associées aux récifs migrent vers le large en hiver. En dehors de la manifeste thermotropie, la relation qui existe entre d'une part les caractéristiques océanographiques et écologiques du milieu dans son ensemble, et d'autre part les poissons de récifs, est un problème qu'il faut résoudre.

(v) Dans les zones où abondent des matières organiques et physiques en suspension (seston et trypton), deux forces antagonistes s'opposent quand on installe un récif: la sédimentation et la bio-construction, cette dernière étant généralement le fait d'organismes sessiles et encroûtants. Les récifs artificiels installés dans des zones eutrophisées ou exposées à des courants chargés de sédiments terrigènes peuvent souffrir de cet antagonisme. Une sédimentation intensive risque de recouvrir et d'étouffer les populations de moules et d'huîtres, par exemple. Dans ce cas, l'homme doit intervenir en prélevant les organismes comestibles (par râclage s'il s'agit de surfaces planes, ou par nettoyage s'il s'agit de cordages et de câbles) et, dans la mesure du possible, rétablir les conditions qui existaient avant la sédimentation.

(vi) Dans certaines zones côtières de la Haute et Moyenne Adriatique, on observe, surtout pendant l'été, une prolifération anormale de certaines espèces d'algues microscopiques, pélagiques ou benthiques (diatomées, dinoflagellées, etc.). Certaines de ces algues (diatomées Pennatae) arrivent à produire des quantités extraordinaires de substance mucilagineuse. On observe parfois, en

été, au moment de ces proliférations anormales, une stratification verticale de la colonne d'eau. De tels phénomènes peuvent avoir une influence sur la zone récifale et sur sa production biologique. En particulier, la masse mucilagineuse flottante peut avoir des effets sur les organismes biologiques présents sur les surfaces exposées ou suspendues et étouffer les organismes sessiles. On a observé pendant 1'année 1988 une mortalité de 40 pour cent des moules présentes sur les récifs artificiels en Adriatique, mortalité due aux nappes mucilagineuses produites pendant 1'été. En revanche, les phénomènes d'hypoxie ne peuvent affecter que la partie inférieure (50-100 cm au maximum) des communautés récifales.

PROJETS ACHEVES, EN COURS OU PREVUS

Situation et besoins aboutissant à des projets

60. Le Président a invité les participants à indiquer les principales raisons pour lesquelles leurs pays respectifs ont été amenés à créer des récifs artificiels et des installations de mariculture. Pour les pays qui n'ont pas encore des structures de ce genre, il a demandé à leurs représentants d'indiquer, selon le cas, les intérêts particuliers de leurs pays dans ce domaine. Concernant l'Italie, il a mentionné les principales motivations ci-après:

(i) La nécessité de protéger la zone littorale contre le chalutage illégal à moins de trois milles de la côte. Cette protection influe toutefois, de façon généralement favorable, sur la faune du fond meuble original.

(ii) La possibilité d'accroître la production halieutique au moyen d'espèces de récif; mais les installations de mariculture ont le même objectif et le même effet. Il est possible aussi, dans les environnements marins riches en production primaire (phytoplancton) et para-primaire (matière organique en suspension) d'associer aux récifs artificiels les objectifs connexes du repeuplement et de la conchyliculture suspendue. Si les zones récifales se répandent en Italie, comme c'est le cas par exemple au Japon et aux Etats-Unis, il faudra s'occuper des questions relatives à l'aménagement des ressources, ainsi que des aspects socio-économiques et, très certainement, des aspects politiques de cette question.

61. Dans les années 50 et 60, plusieurs initiatives individuelles ont été prises en Italie, mais sans un appui scientifique sérieux. Dans les années 70, certaines initiatives ont bénéficié d'un appui scientifique sans néanmoins s'inscrire dans une stratégie d'aménagement; tandis que, dans les années 80, une stratégie d'aménagement de la zone littorale au moyen des récifs artificiels a fait son apparition et, dans le cas des pays membres de la CEE, a été incorporée dans les réglementations No. 2908/83 et 4028/86 relatives aux structures. (Pour de plus amples informations d'ordre historique, on peut consulter les documents suivants: Rapport FAO sur les pêches No. 357, Rome; G. Bombace, 1989 - Artificial Reefs in the Mediterranean Sea, Bulletin of Marine Science, 44(2): 1023-1032; et G. Bombace, 1987 - Iniziative di Protezione e Valorizzazione della Fascia Costiera Mediante Barriere Artificiali a Fini Multipli, LIX Riunione SIPS).

62. Concernant l'Espagne, M. Lopez García a rappelé au Groupe de travail que son pays possède une longue expérience en matière de mytiliculture industrielle, mais que cette activité s'exerce principalement le long de la côte

Atlantique, dans des baies relativement bien abritées. En Méditerranée, le souci principal a été de protéger le milieu marin et certains stocks de poissons, pour des raisons analogues à celles qui ont été citées pour l'Italie, ainsi que de promouvoir la pêche littorale dans des zones défavorisées. Il a estimé aussi que les récifs artificiels devraient jouer un rôle important dans l'aménagement général du littoral espagnol. Il a toutefois exprimé la crainte que des installations récifales très importantes puissent avoir un effet négatif sur le milieu marin; tout dépend des objectifs que l'on se propose et l'Espagne en est encore à ses débuts dans l'expérimentation de ces systèmes.

63. Madame Isabel Moreno (Espagne) a informé le Groupe de travail qu'une évaluation a été faite de tout le littoral des îles Baléares et que des emplacements ont déjà été identifiés en vue de l'installation possible de récifs artificiels (dans les buts indiqués ci-dessus par M. Lopez García). Des études spécifiques de ces emplacements doivent être entreprises et seront suivies après cinq et dix ans.

64. Monsieur Doumenge a rappelé au Groupe de travail que Monaco participe depuis longtemps à l'installation et à l'étude des récifs artificiels en tant que moyen de protéger le milieu marin, mais que leur emploi, nécessairement limité, a été et reste principalement axé sur la reconstitution de la productivité du milieu ouvert. A l'heure actuelle, toutefois, l'étude des récifs artificiels a principalement pour but l'élaboration d'un modèle d'application générale. De plus, à Monaco un projet est en cours d'étude pour implanter au large une ferme aquacole intensive flottante destinée à produire du loup (Dicentrarchus labrax): 120 tonnes annuelles au début et 200 tonnes par la suite. Le dispositif comprend un bateau porte-conteneurs mouillé par 300 à 400 m de fond qui sert d'écloserie et de nurserie. Les juvéniles obtenus à bord seront ensuite élevés dans des cages flottantes (de type en usage en salmoniculture atlantique) disposées à l'abri du bateau. Cet ensemble flottant peut être considéré sous l'aspect d'un véritable récif artificiel.

65. Concernant le Maroc, M. Morchid a expliqué que son pays n'est pas indifférent aux développements enregistrés dans le domaine des récifs artificiels et des installations maricoles. Il s'intéresse plus spécialement à l'aquaculture classique, déjà pratiquée, et serait prêt, le cas échéant, à installer des récifs artificiels le long de la zone littorale, notamment dans les endroits où l'aquaculture classique n'est pas réalisable ou indiquée. Ses principaux objectifs sont d'accroître la production de poissons et d'empêcher le chalutage littoral illégal.

Description des récifs artificiels et des installations de mariculture adoptés

66. Le Président, en introduisant ce point de l'ordre du jour, a noté que, pour réaliser des récifs artificiels, on a utilisé dans le monde les matériaux les plus disparates: pierres, tuiles, vieux bateaux, carcasses de voitures, pneus, matériaux en béton ou en plastique, etc. Ces matériaux ont été utilisés de maintes manières: en amas, en structures semi-organisées, voire en architectures spécifiques quand les modules le permettaient. Plusieurs questions restent encore posées: (i) pour quelles raisons emploie-t-on certains matériaux plutôt que d'autres? (ii) quels sont les matériaux qu'il est préférable de ne pas utiliser? (iii) les modules utilisés ont-ils été conçus en vue d'effets prévisibles? (iv) quel est le rapport optimal corps/espace, c'est-à-dire quelle densité doit avoir la structure récifale pour avoir un effet sur la production halieutique? (v) quel volume minimal

une zone récifale doit-elle avoir pour être correctement aménageable par des pêcheurs professionnels?

67. Pour ce qui concerne l'Italie, après une ancienne expérience faite sans aucun appui scientifique (à Varazze) avec des carcasses de voitures, on a fait récemment des expériences avec des matériaux plus durables (vieux bateaux, chalands, etc.) et avec des modules (blocs de béton) pouvant être assemblés suivant un modèle spécial. Les modules utilisés par l'IRPeM (cubes de béton) ont été préalablement étudiés en vue d'obtenir des effets prévisibles (abris, diversification des habitats, obstacles mécaniques, etc.). Le volume des modules utilisés va de 4 000 à 10 000 mètres cubes environ pour les diverses zones récifales qui ont été créées. Dans certaines zones de l'Adriatique, on a adopté une "unité zonale" qui se compose de 29 pyramides de cinq éléments (4 + 1); un lit de pierres sous chaque pyramide; 12 cages à moules; 116 cylindres de béton pour accroître l'effet refuge; et un certain nombre de petits corps-obstacles munis de crochets. La distance entre les pyramides est d'environ 15 m; les 12 cages à moules sont placées entre les pyramides et les cylindres (4 par pyramide) sont posés sur la face supérieure des blocs de base. Seize zones récifales ont été jusqu'ici créées le long des côtes italiennes: quatre dans le golfe de Gênes, deux dans la mer Tyrrhénienne; deux au nord de la Sicile et huit dans l'Adriatique. Les zones récifales de Rimini, de Cattolica et de Portonovo contiennent chacune trois unités zonales comme celles décrites ci-dessus. Dix autres zones récifales au moins sont actuellement en projet et l'on attend seulement des crédits pour les construire.

68. Monsieur Piccinetti (Italie) a décrit les principaux résultats obtenus dans trois zones différentes de l'Italie. Dans la zone de Fano depuis les premiers essais réalisés en 1980, l'objectif était initialement de prévenir le chalutage illégal; pour cela on a installé une barrière composée de modules cruciformes (tridimensionnels) délimitant une enceinte de quelque 16 km de longueur sur 2 km de largeur. A la suite de son installation, les captures des petits chalutiers opérant juste à l'extérieur de la zone protégée ont augmenté de 30 pour cent. Les poissons qui se trouvent à l'intérieur de l'enceinte échappent au stress imposé par le chalutage et grossissent davantage; mais quand ils migrent hors de l'enceinte, ils sont capturés par les chalutiers. On a constaté plus tard que certaines espèces benthiques vivant sur des fonds vaseux/sableux ne trouvaient pas, dans la zone, de substrats sur lesquels déposer leurs oeufs. Des substrats différents expérimentaux ont été mis en place. Non seulement les poissons, mais aussi certains gastropodes et céphalopodes sont venus déposer ou fixer leurs oeufs et leurs poches embryonnaires sur les blocs. Ce sont les pêcheurs artisanaux eux-mêmes qui ont fait pression pour faire évoluer la zone protégée en ce sens. On a observé une certaine relation positive entre la taille des blocs et la taille moyenne des poissons. Dans une zone de la mer Ionienne au sud de l'Italie, on a immergé des blocs d'environ deux tonnes chacun et divers autres modules qui occupent une surface d'environ 50 km de longueur et 2 km de largeur. L'expérience a été suivie d'observations océanographiques et biologiques et de quelques pêches expérimentales. Dans la zone de Trieste, 1½-3 milles au large, en ce qui concerne la mytiliculture, on utilise depuis longtemps des filières en surface pour l'élevage des moules, mais cette technique n'est pas particulièrement adaptée aux eaux du large. Plusieurs établissements utilisant pour l'élevage des filières de sous-surface (à 3-5 mètres de profondeur) sont en production depuis quelques années. Les résultats sont généralement bons, chaque établissement produit entre 500 et 1 000 tonnes par an et la production actuelle est de 5 000 tonnes en mer ouverte. Les moules ont une bonne croissance; l'élevage à partir d'une taille

de 2-2,5 cm au printemps permet d'atteindre une taille de 6 cm en septembre-octobre.

69. Monsieur Piccinetti a fait remarquer enfin que la situation socio-économique des pêcheurs qui exploitent les installations de mariculture s'est notablement améliorée. Là où le chalutage est interdit et où les blocs sont ancrés sur le fond marin, on assiste à un bon repeuplement des stocks de poisson et la reconversion des pêcheurs des systèmes traditionnels à la mariculture se fait relativement rapidement.

70. Madame Silvia Revenga Martinez de Pazos (Espagne) a brièvement décrit les développements enregistrés en Espagne. Au large de la Galice, on pratique une mytiliculture principalement fondée sur un système de cordages suspendus, tandis qu'en Catalogne on expérimente des filières. Des propositions concernant cinq nouveaux récifs (deux au large de Valence, un devant la côte Catalane, et deux aux îles Canaries) ont été soumises à la CEE en vue d'un financement. Deux autres projets ont déjà été approuvés pour la zone d'Alicante. Des projets strictement nationaux sont également en cours d'exécution, dont deux récifs au large de Valence et un autre sur la côte atlantique. Les modules utilisés sont de deux types: l'un, en forme de tonneau et pesant environ 3 tonnes, est conçu pour empêcher le chalutage illégal. On a déjà constaté qu'il a favorisé un accroissement de la taille moyenne des poissons, qui font maintenant de meilleurs prix; l'autre module est de forme cubique. Sa taille varie selon l'emplacement à l' étude.

71. La situation à Monaco a été décrite dans les paragraphes 60 à 65.

AUTRES ASPECTS ET PROBLEMES

72. Le Président a fait savoir au Groupe de travail que, à propos du point 7.1 de l'ordre du jour, huit communications scientifiques seraient présentées par leurs auteurs respectifs pour servir au débat du Groupe de travail. Ces communications sont reproduites à l'annexe E jointe au rapport. On trouvera ci-dessous un bref résumé des principaux points soulevés dans ces communications et durant le débat.

Aspects et problèmes écologiques et biologiques

73. Le Président a noté que, sous le point 5 de l'ordre du jour, le Groupe de travail avait vu comment la création de récifs artificiels recouvre toute une série d'aspects et de problèmes d'ordre écologique, biologique et halieutique. D'autres questions se posent encore, par exemple: quel est le rôle de l'architecture du récif, de la taille et de l'assemblage des modules du point de vue de la diversité spécifique des populations biologiques qui colonisent le récif? Ce rôle est-il similaire dans d'autres mers? Quel est le rôle joué par les divers facteurs écologiques? Par exemple quel est l'effet des courants, des masses d'eau eutrophisée, des pycnoclines (relation TSD) sur les communautés récifales ou conchylicoles? On sait que la biomasse unitaire des moules est plus importante dans la couche d'eau superficielle qu'en eau profonde et que cela vaut aussi bien pour les moules installées sur des récifs artificiels que sur des systèmes mytilicoles. Quel est le rôle joué par les facteurs édaphiques et par les courants de fond à l'égard de la stabilité des modules récifaux? On pourrait aussi tenir compte des questions liées à la biologie des espèces, aux relations prédateur-proie, à l'utilité de savoir quels sont les réseaux trophiques créés par les récifs artificiels ou par les installations de mariculture dans lesquelles vivent les poissons.

74. Les récifs construits près d'Ancône en 1987-88 ont été systématiquement échantillonnés au trémail et l'on a constaté un accroissement de l'abondance de certains poissons nectobenthiques parmi lesquels les sciaenidés et les sparidés revêtent une importance particulière. Des observations directes (plongeurs) pratiquées autour du récif ont montré que l'abondance des espèces attirées est encore plus grande que celle qu'on avait pu constater dans les captures expérimentales.

75. Les quelques informations disponibles concernant les contenus stomacaux des poissons pris autour des récifs artificiels laissent à penser que ces poissons trouvent une proportion appréciable de leur nourriture dans les zones adjacentes au récif, mais il semble opportun de poursuivre l'étude de cette question. Les conclusions tirées d'études trophiques des récifs tropicaux (coralliens) laissent à penser qu'une bonne partie de l'activité alimentaire des poissons de récifs se déroule pendant la nuit au voisinage du récif.

76. Il faut évidemment quantifier la contribution des organismes récifaux sédentaires à la chaîne trophique qui aboutit à la production de poisson proprement dit. C'est le cas notamment pour les moules, dont une proportion appréciable se perd durant la croissance. Il a été suggéré, en tant que méthode expérimentale pour étudier ce phénomène, de protéger au moyen de filets certaines surfaces contre la prédation.

77. Ce que l'on ne sait pas très bien c'est si le rôle essentiel des récifs artificiels est lié à la contribution trophique ou bien à la fourniture d'un abri. Il reste à montrer que la limitation alimentaire constitue une contrainte importante, en particulier si l'on considère les forts taux d'exploitation actuelle des espèces commerciales.

78. Des expériences de mytiliculture sur cordes suspendues ont été réalisées en Adriatique avec de bons résultats; on a pu récolter des moules et deux espèces d'huîtres, qui ont atteint une taille commerciale en l'espace d'un an. Diverses méthodes de culture sur cordes et sur plateaux ont été étudiées. Le rendement (7 kg de moules/kg de naissain et 10-15 kg de naissain de moules par mètre de corde) a été satisfaisant malgré le ralentissement de la croissance pendant l'hiver.

Aspects et problèmes technologiques

79. Le Président a fait observer que, bien que des progrès considérables aient été accomplis en matière de conception, de production et d'assemblage des modules composant les récifs artificiels, il y a encore place pour de nouveaux développements et pour une spécialisation ultérieure. On commence à se faire une certaine idée du volume optimal d'un récif artificiel mais on ne dispose encore que de peu de données fiables concernant la taille optimale, si elle existe, d'un système récifal (parc récifal) et la densité optimale des unités récifales d'un système donné.

80. Parlant de l'expérience italienne (IRPeM), il a décrit la façon dont on installe un récif artificiel sur le fond marin pour qu'il reste longtemps stable. En particulier, on place maintenant le lit de pierres sur deux gabions métalliques posés l'un à côté de l'autre sur le fond, en carrés de 7 par 7 m. On aligne les blocs au moyen de barres métalliques insérées dans des trous pré-formés dans les blocs de la base et de la couche supérieure. L'opération peut s'effectuer assez rapidement à partir d'un bateau spécialement équipé. M. Bombace a ensuite décrit un certain nombre de solutions qui facilitent l'installation et la fixation des filières employées pour la

mytiliculture, solutions dont pourrait s'inspirer d'autres institutions qui commencent à s'intéresser à ces questions.

81. Le Groupe de travail a noté que plus de 200 types différents de récifs artificiels et de modules ont été expérimentés et que nombre d'entre eux se trouvent maintenant dans le commerce; certains ont été conçus dans des buts très précis.

Aspects et problèmes halieutiques

82. Les principales informations supplémentaires communiquées ont porté sur les méthodes utilisées pour prélever le poisson autour du récif.

83. En Italie, le filet maillant reste la principale méthode utilisée pour récolter le poisson tandis que, pour favoriser la production de moules et faciliter leur prélèvement on utilise des cages placées entre les modules récifaux.

84. En Espagne, on utilise des sennes coulissantes pour pêcher l'anchois et des palangres pour les espèces de plus grande taille; au voisinage immédiat des récifs artificiels, on pratique le chalutage et aussi les petits métiers.

85. Le Groupe de travail a estimé que, si l'une des fonctions importantes des récifs artificiels et des systèmes de mariculture est d'améliorer le revenu des pêcheurs artisanaux, et de leurs communautés, dans la région méditerranéenne, il serait utile cependant d'expérimenter d'autres méthodes, peut-être plus modernes et mieux adaptées, pour prélever les poissons et mollusques d'un récif. L'utilisation de la lumière (en tant que procédé FAD avant la capture), d'ondes sonores, de champs électriques, etc., offre peut-être des possibilités d'innovation dans ce domaine.

Aspects économiques et sociaux

86. Monsieur Doumenge (Monaco) a confronté la situation au Japon avec celle qui prévaut en Méditerranée. La création des Zones économiques exclusives a compromis les moyens de subsistance de beaucoup de japonais pêchant dans les eaux lointaines et un gros problème de reconversion s'est posé, qui est venu s'ajouter à la très ancienne pénurie de terres agricoles. Tout ceci a fortement favorisé le développement des RAIM au Japon. En Méditerranée, la surpêche ou la détérioration (par la pollution) des stocks de poissons, quoique évidentes, ne constituent pas un facteur économique suffisamment solide pour surmonter les résistances cachées qui freinent tout nouveau développement de la zone côtière, d'autant que le rôle des pêches dans les économies nationales est encore très restreint. Il a aussi souligné la grande diversité des situations nationales en Méditerranée, qui peuvent ou non favoriser le développement des RAIM. Il a noté en particulier qu'en France, là où les pêcheurs côtiers artisanaux sont peu nombreux, on a tendance à utiliser les récifs artificiels pour promouvoir la pêche sportive.

87. Quelques participants se sont déclarés préoccupés par le coût des RAIM, en particulier si on en limite l'emploi à certains objectifs seulement.

88. Monsieur Bombace (Italie) a expliqué que, d'après l'expérience de l'IRPeM, le gros des coûts porte sur la fabrication, le transport et l'installation des structures. Un bon système récifal devient très rapidement rentable, en deux à trois ans.

89. Le Groupe de travail a noté que l'un des éléments importants en faveur de la création des RAIM est leur effet positif sur la situation sociale des pêcheurs artisanaux, non seulement au Japon mais aussi en Méditerranée.

Aspects et problèmes administratifs et juridiques

90. Il a été reconnu que la situation administrative et juridique est assez différente dans chaque Etat membre, ce qui ne permet pas d'aboutir à des conclusions détaillées. Le Groupe de travail a cependant remarqué que, presque partout, quand on essaie de créer des zones récifales et des installations de mariculture en mer ouverte, des obstacles d'ordre administratif et juridique viennent freiner la réalisation de telles installations. Dans bien des cas, ces difficultés peuvent être dues à une méconnaissance de la nature et des objectifs de ces structures. Parfois, les récifs artificiels destinés à d'autres usages que la production halieutique sont assimilés, par l'Administration, à la mariculture pure et simple et cette dernière, par les hasards de l'évolution sociale, est souvent rattachée à l'agriculture classique.

91. Il règne aussi, dans la pratique, une certaine incertitude au niveau du législateur car l'autorité qui s'exerce sur la zone côtière dépend souvent de la distance à laquelle se trouvent les installations par rapport à la côte. Il importe donc non seulement d'étudier la situation juridique dans chaque pays mais aussi de chercher à atténuer les entraves juridiques et administratives qui empêchent la création de zones récifales, c'est-à-dire de faciliter l'octroi de permis d'installation et d'exploitation de ces systèmes récifaux dans le cadre de la politique globale des Etats membres du CGPM.

PROGRAMMES SCIENTIFIQUES D'ACCOMPAGNEMENT

92. Pour appuyer d'une manière scientifique les initiatives d'installation de récifs artificiels, surtout les récifs qui visent à augmenter la production halieutique mais aussi toute installation dans la bande côtière, il faudrait définir des lignes de recherche concernant le milieu, l'organisation de la pêche, les matériaux, les aspects socio-économiques et juridiques de l'octroi des espaces littoraux. Les recherches à entreprendre ont été examinées sous les rubriques ci-après.

- **Etude du milieu**: Avant de consacrer d'importants investissements à la construction de récifs de taille commerciale, il faut établir clairement les conditions hydrographiques et sédimentologiques favorables à l'installation de récifs artificiels, leur emplacement géographique et leur bathymétrie. Les études du milieu préconisées sont: hydrographiques (courants, vagues, pycnoclines, fronts thermohalins, etc.); hydrobiologiques (sels nutritifs, production primaire et secondaire, matière organique en suspension, etc.); des fonds (notamment la sédimentologie); et des effets des installations récifales et conchylicoles sur le milieu;

- **Etudes biologiques**: Il a été démontré que la situation saisonnière et la succession écologique des communautés biologiques présentes sur différents emplacements sont très variables; il n'est pas certain, dans tous les cas, que cette succession aboutisse inévitablement à une situation de climax. Il semble souhaitable d'effectuer un échantillonnage biologique et halieutique de la zone d'intérêt, ou bien un échantillonnage parallèle dans des zones témoins similaires, avant de procéder à l'installation d'un récif artificiel.

- Les taux de croissance et de mortalité des espèces encroûtantes et leur contribution trophique à des chaînes alimentaires d'importance commerciale doivent être établis. Les taux de recrutement d'espèces telles que les moules et les huîtres sur le récif doivent être suivis régulièrement et il faut obtenir des informations sur les variations de la diversité biologique et les changements saisonniers. Il faut, en outre, étudier davantage les **matériaux et modules immergés**: recherches sur la colonisation des substrats fournis par les matériaux et modules récifaux immergés et l'éthologie alimentaire, les phases délicates du cycle biologique des espèces vagiles, surtout celles économiquement importantes, leur diversité spécifique, changements saisonniers, etc.

- Il faut poursuivre l'étude du rôle potentiel et réel des récifs artificiels et autres obstacles dans le découragement du chalutage illégal, et en particulier de leur efficacité en ce qui concerne la protection des communautés de poissons démersaux et des zones d'alevinage littorales, ainsi que l'évaluation de biomasse par des techniques visuelles. Ce genre d'études comparatives mérite priorité, malgré les difficultés pratiques que pose ce type d'expérience sur le terrain. Lorsque les zones récifales connaîtront une extension considérable, on pourra mettre sur pied des recherches visant à comparer les captures effectuées dans les zones proches des récifs et les captures effectuées plus au large.

- **Recherche technologique**: Il faut rassembler une expérience en ce qui concerne l'installation de structures artificielles spécialement conçues dans un but déterminé (par exemple, protection d'habitats critiques, mariculture, concentration du poisson, zones d'alevinage) et diffuser l'information auprès des utilisateurs potentiels. Les critères de stabilité des récifs installés sur différents types de sédiments benthiques doivent être étudiés plus avant et des modèles récifaux appropriés mis au point. Il faut aussi améliorer les techniques de capture et d'échantillonnage des espèces récifales.

- **Considérations socio-économiques**: Il faut, d'une manière générale, réunir une documentation concernant les coûts de production, de transport, d'entretien et de surveillance des récifs artificiels de façon à pouvoir entreprendre un jour une évaluation économique des résultats des récifs artificiels.

- Il est absolument indispensable d'associer, dès le début, les pêcheurs au choix de l'emplacement et à la construction du récif si l'on veut intégrer avec succès cette technologie dans les opérations de pêche littorale. Pour faciliter la répartition des lieux d'implantation des récifs artificiels et autres installations, il est nécessaire d'étudier l'organisation des pêcheurs dans la zone intéressée, les situations conflictuelles qui peuvent exister, les métiers intéressés, les aspects économiques de leur activité, etc.

- **Parcs marins**: Le rôle potentiel des récifs artificiels et d'une aquaculture pouvant leur être associée dans la protection des régions côtières suivant un système de "réserves de la biosphère" a été examiné. Il a été reconnu que le noyau de protection absolu qui doit assurer la protection de biotopes et d'espèces clés ne doit pas faire l'objet d'interventions autres que des mesures destinées à permettre le bon fonctionnement des processus naturels. Par contre, pour être efficace, le périmètre des réserves côtières de la biosphère doit

s'étendre sur plusieurs milliers d'hectares. Ceci implique d'accompagner la protection par des mesures d'aménagements de la zone périphérique (buffer zone) et surtout dans une large zone de transition. Pour admettre les contraintes indispensables, les populations locales doivent pouvoir bénéficier d'aménagements les amenant à s'associer au fonctionnement de la réserve. Dans ce sens les récifs artificiels peuvent assurer une augmentation des ressources renouvelables. Les techniques aquacoles pouvant être associées à l'implantation des récifs artificiels sont aussi susceptibles de fournir des emplois de substitution pour ceux qui peuvent être affectés par les réglementations très strictes indispensables à la protection et au fonctionnement d'une réserve côtière de la biosphère.

- **Mariculture:** Il a été souligné que l'actuelle base de données de la FAO sur la mariculture a besoin d'être améliorée, notamment en ce qui concerne les moules et autres mollusques de la région méditerranéenne. Le Secrétariat a décrit les mesures prises actuellement pour améliorer cette base de données et a demandé aux Etats membres du CGPM de coopérer à ce travail.

- Parmi les recherches importantes à entreprendre, on a mentionné la nécessité de chercher la relation qui puisse exister entre les opérations de mariculture et les épisodes de marées rouges observés en Méditerranée. De même, l'effet des matières mucilagineuses et des biotoxines produites par des diatomées et autres floraisons phytoplanctoniques, conséquences de l'eutrophisation des eaux côtières, doit aussi être étudié, en particulier du point de vue de l'incidence de ces phénomènes sur les récifs artificiels et sur les installations de mariculture produisant des mollusques.

93. Le Groupe de travail a insisté sur la nécessité d'un financement régulier des programmes de recherche accompagnant l'installation de nouveaux récifs et le développement de la mariculture. Il est certain qu'il existe, en dehors de la Méditerranée et spécialement au Japon, un volume considérable d'expériences propre à encourager la création de nouveaux récifs. Mais les conditions qui règnent en Méditerranée sont particulières à cette zone et l'on constate déjà des différences appréciables entre, par exemple, la mer Adriatique et la mer Tyrrhénienne.

94. Dans le cas de l'Espagne, il a été dit que, dans le cadre du Règlement (CEE) 4028/86 du Conseil, 15% des investissements sont dédiés aux recherches connexes.

PERSPECTIVES

95. Le Président a expliqué que, à long terme, la mise en place et l'exploitation soutenue des zones récifales et de la mariculture en mer ouverte ont pour but d'une part de développer la pêche et d'autre part d'élever le niveau de vie du pêcheur côtier. D'autres buts ont été évoqués pendant les débats, à savoir améliorer la gestion de la zone côtière et la protection de cette zone (dont l'existence exige un meilleur contrôle de la qualité de l'eau de mer).

96. Il a été remarqué qu'un effort accru est nécessaire pour améliorer la collaboration et la coordination entre les diverses entités nationales concernées et, d'une manière générale, l'information du grand public à ce sujet.

97. Tout cela implique une meilleure prise de conscience et le développement d'une volonté politique au niveau national surtout, mais aussi international.

98. Le Groupe de travail a été informé des intentions de la Banque mondiale et de la Banque européenne d'investissement d'appuyer des études et des projets devant assurer la protection de la Méditerranée.

99. Comme toutes ces questions concernent directement la pêche sous toutes ses formes, le Groupe de travail a exprimé sa surprise que le CGPM n'aie jusqu'ici pas été invité à collaborer aux diverses études devant être menées par ces institutions. Il a demandé au Secrétaire du CGPM de se mettre en contact avec elles en vue d'instaurer une collaboration adéquate dans les domaines d'intérêt commun. Le Groupe de travail a par ailleurs demandé à M. Doumenge, lorsqu'il participera au séminaire organisé sur le programme de protection et développement de la Méditerranée (Paris, 7-8 décembre 1989) de faire part aux organisateurs des inquiétudes exprimées à ce propos par le Groupe de travail.

100. L'observateur du Plan Bleu (PNUE), en transmettant à la réunion les voeux de succès de l'Organisme qu'il représentait, a indiqué que le Plan d'action pour la Méditerranée, mis en place en 1975 à la suite de la Conférence organisée à Barcelone par le PNUE sur la protection de la Méditerranée contre la pollution, était engagé dans un exercice de prospectives à long terme (horizon 2025) des activités économiques essentielles de la Méditerranée. Cet exercice s'est déjà traduit par la publication d'un ouvrage de base "le Plan Bleu - Avenirs du Bassin méditerranéen" et d'un résumé de cet ouvrage comportant des orientations pour l'action; un fascicule sur les perspectives offertes par les pêches et l'aquaculture est en préparation. Ces divers documents soulignent l'importance que pourra revêtir l'aquaculture en mer ouverte dans un contexte de développement situé cependant dans le cadre d'un aménagement rationnel de l'environnement côtier et marin. Le Plan Bleu considère donc avec un particulier intérêt cette initiative du CGPM et est heureux de pouvoir se tenir directement informé, grâce à sa représentation à cette réunion, des conclusions du Groupe de travail.

101. Le Groupe de travail sur les récifs artificiels et mariculture, établi lors de la dix-neuvième session du Conseil général des pêches pour la Méditerranée (mars 1989), qui s'est réuni à Ancône du 27 au 30 novembre 1989, après avoir discuté les différents problèmes concernant les récifs artificiels et les installations de mariculture en mer ouverte, est arrivé aux conclusions et recommandations suivantes:

(i) Etant donné que des interactions écologiques, technologiques, et socio-économiques complexes caractérisent la réalisation et la gestion des aménagements des sites côtiers, il est indispensable de développer et d'approfondir la recherche scientifique au moyen d'équipes pluridisciplinaires pour améliorer les technologies, évaluer les résultats, et rechercher par quelles voies optimiser les rendements.

(ii) Les expériences réalisées et en cours enseignent que seuls des investissements en très nette augmentation permettront d'obtenir des résultats susceptibles de transferts. Il convient donc d'appuyer la recherche fondamentale et appliquée par des financements à moyen et à long terme. Il est aussi nécessaire de trouver des voies permettant de couvrir les premiers investissements des implantations. Il apparaît donc nécessaire de demander aux institutions internationales concernées par la protection et le développement des rivages méditerranéens d'attribuer une partie de leur budget à ces objectifs.

(iii) La réalisation des récifs artificiels doit être programmée et suivie par des recherches scientifiques et des études technologiques adéquates.

(iv) Les résultats sont liés à l'intégration des projets dans le cadre d'une gestion globale du littoral s'étendant sur de vastes périmètres et englobant des unités socio-économiques viables. Un seuil minimum d'efficacité nécessite des implantations d'une ampleur adéquate.

(v) Il est nécessaire de faciliter les démarches administratives et juridiques pour promouvoir les installations des récifs artificiels et de mariculture.

102. Le Groupe de travail a fait appel aux autres organisations internationales concernées par la mise en valeur et l'investigation de la zone côtière, en général, et des récifs artificiels et installations de mariculture en mer ouverte en particulier, pour collaborer, dans le cadre de leurs mandats respectifs, avec le Conseil général des pêches pour la Méditerranée dans le but de promouvoir ladite mise en valeur de ces structures dans la zone du CGPM, d'une façon soutenue tout en améliorant la qualité du milieu marin. Il fait appel, en particulier, mais sans aucune exclusive, à la Commission internationale pour l'exploration scientifique de la mer Méditerranée (CIESM), au Programme des Nations Unies pour l'environnement (PNUE), au Programme des Nations Unies pour le développement (PNUD), à la Commission océanographique intergouvernementale (COI), à la Banque mondiale (BM), à la Communauté économique européenne (CEE), à l'Organisation pour la coopération et le développement économiques (OCDE), à la Banque européenne d'investissement (BEI), et au Conseil de l'Europe (CE).

103. Le Groupe de travail a demandé au Secrétaire du CGPM de faire tout son possible, dans les limites de ses pouvoirs, pour donner effet aux recommandations ci-dessus et les faire mettre à exécution, en consultation avec le Président et les Vice-Présidents du CGPM et avec le Président du Comité du CGPM de l'aménagement des pêcheries.

ADOPTION DU RAPPORT

104. Le Groupe de travail a adopté le rapport de sa première session. En même temps, il a accordé au Secrétaire le minimum de liberté de rédaction nécessaire à la production de la version finale. En particulier, il lui a demandé de regrouper sous le paragraphe 90 (suggestions introductives de recherche scientifique d'accompagnement) les paragraphes 93 à 102 (suggestions de recherche convenues par le Groupe de travail), en vue d'éviter une répétition des idées, et de compléter les points 10 et 11 du rapport.

CLOTURE

105. Monsieur Lopez García (Espagne), au nom des participants, a exprimé sa satisfaction quant au niveau et à l'utilité des discussions. Il a remercié le Président de son habileté à conduire la session. Il a aussi remercié la Regione Marche et l'Istituto di Richerche sulla Pesca Marittima pour leur hospitalité à accueillir la première session du Groupe de travail, ainsi que pour les excellentes facilités mises à sa disposition pour le bon déroulement de celle-ci, y compris les nombreuses fonctions sociales. En même temps, il a remercié le Secrétariat et le personnel d'appui pour leurs services efficaces.

106. Le Président s'est associé à ces aimables sentiments.

107. Il a ensuite demandé si le Groupe de travail voulait exprimer ses idées sur la date et le lieu de la prochaine session. Le Groupe de travail a exprimé le souhait de se réunir de nouveau en 1991. Il n'y avait cependant aucune offre sur le moment de la part d'un des représentants nationaux d'accueillir la deuxième session dans son pays.

108. Le Secrétaire a expliqué que le Groupe de travail était sensé rendre compte d'abord au Comité de l'aménagement des pêcheries. Or, il étudierait la question sérieusement en vue de réaliser le souhait exprimé par le Groupe de travail, mais la deuxième session devrait avoir lieu en tout cas après la prochaine session du Comité qui devrait lui, se réunir quelques mois avant la prochaine session du Conseil lui-même.

109. Le Président a alors déclaré la session close à 18 h 55 le 30 novembre 1989.

OPENING

1. At the kind invitation of the Italian Government and the Regione Marche, the GFCM Working Party on Artificial Reefs and Mariculture was held from 27 to 30 November 1989 on the premises of the Fair of Ancona, with the active collaboration of the Director and staff of the host institution, the Istituto di Ricerche sulla Pesca Marittima (IRPeM), Consiglio Nazionale delle Ricerche (CNR), Ancona.

2. The Director, Mr Giovanni Bombace, first invited Mr Giuseppe Maggio-Aprile, the Representative of the Ministero della Marina Mercantile, Direzione Generale della Pesca, to address the participants.

3. Mr Maggio-Aprile stressed the importance of artificial reefs not only to Italy but also to the other Member Nations of the GFCM. The establishment of artificial reefs, and any associated mariculture, was, in his view, a new road to modern fishery development and management. This First Session of the Working Party would, he believed, provide an excellent opportunity to exchange experience, whether positive or otherwise, between the interested Member Nations of GFCM and their concerned institutions. It could also help to provide a basis for further action by the Member Nations, and convey an encouraging message to politicians and other decision-makers. Mr Maggio-Aprile expressed his Ministry's particular appreciation of the efforts of the Regione Marche and of Mr. Bombace and his staff at IRPeM to develop this particular activity in Italy, in general, and in the Adriatic region, in particular.

4. Mr Marco Bellardi, on behalf of the Assessore alla Pesca della Regione Marche, likewise expressed the Regione's appreciation of the efforts of Mr. Bombace and his staff to study and test artificial reefs in the middle Adriatic Sea. He saw artificial reefs as an important potential mechanism of fishery management and development. Within this framework, he believed that artificial reefs and mariculture would help to stabilize the fish market, assist in the development of coastal sport fishing, and in the conversion of small-scale fishermen from a declining artisanal fishery to one based on artificial reefs and mariculture, which he saw also as a means of restocking some highly exploited fish stocks. Finally, Mr. Bellardi stressed the Regione Marche's interest in promoting cooperation between the Member Nations of GFCM with a view to advancing this relatively new form of fishery development and management.

5. The Mayor of Ancona, Mr Franco del Mastro, welcomed the participants to his city, pointing out its long history as a trading and fishing port, which had provided a basis for the Regione's socio-economic development. Mr del Mastro warmly welcomed the initiative of the GFCM and IRPeM in establishing and promoting the Working Party. He saw the development of artificial reefs as a key to the development of small-scale fishing that would improve protection of the coastal zone, promote restocking of overfished resources, and lead to the development of offshore mariculture. It would also, by conversion of fishermen, take up some of the excess fishing capacity in the small-trawl fishery in the region. He recognized that there were still numerous problems to be solved: those of an administrative, juridical and management nature, among others, and looked to the Working Party as an important source of guidance and advice in this area of fishery development. This would, he said, require a close link between research and economic development. The Mayor invited the participants to visit his city, with its rich artistic and historical heritage.

6. The Secretary of the Council, Mr Ray C. Griffiths, thanked the Italian authorities who had made it possible and appropriate to hold this First Session in Ancona: the Ministero della Marina Mercantile, the Regione Marche, the Mayor of Ancona, the Consiglio Nazionale delle Ricerche, and the Istituto di Ricerche sulla Pesca Marittima; he particularly thanked Mr Bombace and his staff for their warm welcome and assistance.

7. Mr Bombace recalled that the subject of artificial reefs and suspended shellfish culture in the Mediterranean had been taken up in three international meetings: (i) at the Symposium on the Management of Living Resources of the Coastal Zone in the Mediterranean, held in Palma de Mallorca in 1980; (ii) at the Journées d'Etudes of ICSEM on the Scientific Aspects of Artificial Reefs and Suspended Mariculture, held in Cannes in 1982 (Proceedings published in 1983); and (iii) at a GFCM Technical Consultation on Open-sea Shellfish Culture in Association with Artificial Reefs, held in Ancona in 1986, the report of which was published as FAO Fisheries Report No. 357.

8. In view of the important contributions made by French and Bulgarian experts to the aforementioned Technical Consultation, the Working Party expressed its particular regret that there were no representatives from France and Bulgaria at this First Session of the Working Party.

9. Several national meetings on the subjects of artificial reefs and mariculture have also been held, notably in Italy, and, in the last ten years, many artificial reef zones have been set up in the Mediterranean area. The subject has therefore grown in importance and now opens up new possibilities for coastal fisheries; it now calls for the increased attention of legislators and fishery administrators. Mr Bombace recalled that it was for such reasons that the GFCM, at its Nineteenth Session in Livorno in March 1989, decided to create a Working Party to deal specifically with the subject. The decision was, he stressed, taken unanimously by all the Member Nations present. He informed the Working Party that the Societá Italiana di Biologia Marina had established a Committee on Artificial Reefs.

10. Mr Bombace then read out the Terms of Reference of the Working Party by way of guidance for the development of the work of the present Session. He stressed the fact that the Working Party had been given a heavy responsibility to study and evaluate the various principal aspects of the development of artificial reefs and mariculture installations, with a view to suggesting possible useful approaches, taking into account experience elsewhere in the world. He was therefore perplexed by the reserve still apparent, mainly at the intellectual level, with respect to artificial reefs; such reserve was not nearly so evident among fishermen, administrators and politicians, and he hoped that the Working Party would help to dissipate it.

11. Mr Bombace then invited Mr François Doumenge, the Director of the Musée Océanographique de Monaco, and Secretary-General of the International Commission for the Scientific Exploration of the Mediterranean Sea (ICSEM), to give the keynote speech for the Session.

12. Mr Doumenge reviewed in some detail the most recent developments in the field of artificial reefs and mariculture, particularly in Japan and the USA. His keynote speech is given in full in Appendix D hereto.

ADOPTION OF THE AGENDA

13. The Working Party adopted the Provisional Agenda; the Agenda is attached as Appendix A hereto.

ELECTION OF THE CHAIRMAN AND VICE-CHAIRMAN

14. Mr Abdelkadous Morchid (Morocco) proposed Mr Giovanni Bombace (Italy) for the post of Chairman of the Working Party. This proposal was seconded by Mr Lopez García (Spain). Mr Bombace was elected unanimously.

15. Mr Maggio-Aprile (Italy) proposed Mr Youssef Ouati (Morocco) for the post of Vice-Chairman. This proposal was seconded by Mr Bounouni (Algeria). Mr Ouati was elected unanimously.

CONDUCT OF THE SESSION, TIMETABLE AND DOCUMENTATION

16. The Secretary provided guidelines for the conduct of the Session; in particular, the possibility, if necessary, of forming sessional working or drafting groups to deal with specific issues, and day-by-day preparation of the Draft Summary Report so as to facilitate its adoption. He briefly outlined the documentation.

17. A question of definition of terms (artificial reefs, mariculture) was raised but is dealt with in paragraphs 28 to 39 of this Report.

18. The List of Participants is given in Appendix B hereto.

THEORY OF ARTIFICIAL REEFS AND MARICULTURE INSTALLATIONS

19. The Chairman introduced this item. He first returned to the objection, with respect to artificial reefs, that some scientists have advanced, mainly from the theoretical point of view. The objection is essentially as follows. Artificial reefs do not create a new biomass, but are simply devices for attracting and concentrating biomass already in existence in a particular area; such an objection refers especially to fish. Thus, given a fishery in which the fish or other target organisms are spatially distributed in a certain way, the creation of artificial reefs would lead only to an aggregation of species within a certain radius, as a function of the power of attraction (of the reef), which is referred to as "thygmotropism".

20. The aforesaid objection may be met by reference to the two principal stock parameters, mortality and growth. If artificial reefs have the possibility, for the species of interest, to modify the mortality-time and growth-time curves in some way, the result is a modification of the curve for the stock biomass, which is the product of the two curves mentioned above.

21. There is little doubt that the establishment of artificial substrates, the creation of various kinds of habitats and the provision of cavitated structures increase the protection of juveniles of species attracted to an artificial reef. Scientists who study artificial reefs, and fishermen who catch adult or juvenile fishes in the vicinity of artificial reefs, know that the cavitated structure of the reefs certainly protects young fish. This protection, which is reflected in increased survival in the pre-recruitment phase, must reduce the slope of the mortality curve and, consequently, the biomass of the adult stock is greater. This relationship is, however, rather difficult to demonstrate scientifically. In effect, one is working within an open system in which there is an energy exchange between the reef structure and the surrounding space.

22. Further research on this problem is needed so as to provide qualitative and quantative data required to demonstrate the real reduction in mortality at

the level of the reef system (supporting research is dealt with further in paragraphs 92 to 94 below).

23. There are no major problems with respect to edible sessile forms (for example, sestonophagous bivalves such as mussels, oysters, etc.) that are subjected to harvesting by man.

24. For the latter, solid supports such as suspended cables or ropes, and structures of concrete or other materials, mitigate the limiting factor which, for sessile organisms, is the surface available for the fixation of their larvae. The development of the young and the increase of the biomass depend on the richness of the environment in terms of primary and secondary or paraprimary (suspended organic material) production.

25. As to whether the reef structure promotes the growth of mobile marine organisms that live near or in the vicinity of the reef, the following argument may be advanced: the new surface made available for colonization, the cavitated structures, the various settlement strategies adopted by sessile organisms, and the diversity of habitats, bring about the establishment of new and different trophic webs. The question is, do the latter have an effect on the growth of the reef species as a result of a greater availability of food than previously? Even here, the answer is probably yes, but this assertion must be supported by scientific data.

26. Research aimed at answering this question should conceive the experimental modalities. At present, one can observe juveniles swimming around the reefs, and fish feeding on prey in the cavities and cracks; one finds fish in which their thygmotropism enables them to feed on preferred prey in the vicinity of, or inside, the artificial reef. Direct observation and, even more, the analysis of stomach contents, could provide support for these ideas but they must also be demonstrated by quantitative data and experimental research. Direct observation alone is not sufficient.

27. It is also important to determine to what extent an artificial reef or reef system can affect the growth curve (weight-time; weight-age) of the individual fish, on the one hand, and the real abundance (number) of fish (of a given species), on the other, since both factors contribute to determining the stock biomass. The relative importance of these two factors may depend on the species of interest.

Definition

28. Regarding the definition of artificial reefs, there are three main types briefly described in paragraphs 29-31; moreover, the substrates, the elements, the materials and the structures used, as well as the spatial density of the reef units, follow certain strategies.

29. There are, for example, reefs aimed solely at impeding illegal trawling; that is, physical obstacles to trawlers are placed on the sea bed in a zone to be protected, particularly inshore. This hindrance has a biological effect, by allowing an increase in size and weight of young fish near the original bottom that would otherwise have been captured by illegal trawling.

30. There are also reefs that, from the structure of the modules employed, the strategy followed, and the possibilities they offer for shellfish culture, can be classified as multi-purpose artificial reefs. These are generally the type set up in the Adriatic by the Istituto di Ricerche sulla Pesca Marittima (IRPeM).

31. Finally, there are special reefs, made of a particular kind of module, aimed at favouring a given species or to generate changes in certain environmental parameters.

32. The approach to suspended shellfish culture is more or less the same. Solid supports are placed on the bottom. End cables carry buoys, with horizontal lines from which hang ropes for the fixation of larvae or for suspending bags, to allow the growth of seed mussels. Smaller floats are attached to each line to alleviate the strain due to the weight of the mussels.

33. In some countries, structures (generally cables, ropes, plastic lines, tied car tyres, etc.) have been attached to the bottom and left to float freely at the unattached end; these structures attract and concentrate pelagic fishes. Such structures are usually called FADs (Fish-Attracting Devices).

34. Mr. Bombace asked whether there is a connection between these different types of structure and whether it is possible in some way to cover the examples mentioned above in a single definition, since artificial reefs are certainly also FADs; that is, a means of attracting and concentrating various kinds of marine organism. Artificial reefs, FADs or any other method of aggregation, including shellfish-culture installations, have the same objective: to increase the fish-productivity of the environment.

35. Regarding an overall definition, it was suggested that artificial reefs, systems for the attraction and aggregation of organisms, and suspended-mariculture installations, are structures that: are set up by man on or in the sea bed, or even in only partial contact with it, possibly extending to the upper layers of water by means of suspended systems; use simple technology and bio-ecological strategies and mechanisms; and are aimed at increasing the fish productivity of the environment and/or concerning certain areas of the sea bed.

36. Mr Lopez García (Spain), however, pointed out that, in Spain, as well as in the EEC, a real distinction is made between artificial reefs and mariculture (in the sense of industrial production of fish or shellfish by man in the sea), and believed that the latter did not fall within the purview of the Working Party. He doubted that oil rigs, for example, could be covered by the proposed definition. In his view, artificial reefs are intended to protect fish and shellfish stocks and the coastal marine environment, rather than to produce industrial amounts of fish or shellfish.

37. Mr Bombace pointed out that artificial reefs, by protecting fishing grounds, increase the production of fish and no distinction could be precisely made between industrial and non-industrial quantities, as the Japanese experience, so far, had shown.

38. Mr John Caddy pointed out that, in any case, artificial reefs and mariculture installations (ARMIs), whatever their nature, could only be effectively considered if placed within a framework of coastal-zone management. (This question is taken up in more detail in paragraphs 58 to 59 below.)

39. On this point, Mr Lopez García (Spain) pointed out that mariculture installations have different objectives and techniques and should not be simply considered as a supplementary factor from the standpoint of coastal management.

Ecology

40. In introducing this item, Mr. Bombace posed a general but important question which relates also to Agenda Item 5.3: How is this increase in fish production obtained? He offered the following answers as a basis for discussion of Agenda Items 5.2 and 5.3.

(i) By recycling energy (by the fixation of the larvae of sestonophages such as bivalves used by man - mussels, oysters, etc.).

(ii) By reducing larval and juvenile mortality. This reduction in mortality is obtained in various ways as a function of the ecophysiological requirements and needs of different groups of animals. For example, for sessile invertebrates, surfaces of whatever kind, such as flat surfaces, cables, etc., are needed for larval fixation. For swimming forms, especially nekto-benthic fishes, open cavities are required, so as to provide juveniles with hiding places or to aid camouflage. For sedentary benthic forms, enclosed cavities are acceptable, whereas for the large decapods a series of cavities of increasing size is necessary to provide a refuge for recently molted animals which, at that time, increase in body size.

(iii) By attracting and concentrating organisms. Various kinds and systems of attraction and concentration may be used (various kinds of bait, light, small compressed-air bubbles, as well as floating bodies such as the "kannizzati" used in the south of Italy and in Malta for shadow fishing, or bodies floating near the surface, etc.) The effect is plain to see in certain pelagic species. Even when the attraction does not consist of bait-food, the fish approach a reef in the expectation of finding prey. The technical term is thygmotropism (or even thygmotactism), but we still do not understand the underlying mechanism well; perhaps it is a question of trophism.

(iv) By creating new food webs determined by the new spaces, habitats and colonization patterns. Several species of invertebrates or plants can meet their ecological needs through these new food webs and this gives rise to a qualitatively diversified source of food for the third trophic level.

(v) By protecting the sea bed or, better still, the pristine fauna of sandy-silt bottoms on which obstacle reefs have been placed. Illegal trawling is prevented and this allows an increase in size, hence weight, of individuals (and possibly in numbers) and thus of the fishable biomass.

41. Mrs Isabel Moreno (Spain) pointed out the fact that not all artificial reefs lead, as one might think, to an increase in diversity of the fauna in the area in which they are established, particularly if they are designed to promote the abundance of the biomass of particular species.

42. Mr Abdelkadous Morchid (Morocco) stressed the importance of determining the energy flux between the sessile and the vagile organisms, and the relationship between a reef (or reef zone) and the surrounding area.

43. Mr Doumenge (Monaco) suggested that the problem was particularly crucial in respect of pelagic species, and needs long-term studies over an extensive

area around a reef (or reef system). He pointed out the fact that the behaviour of skipjack (Katsuwonus pelamis), which has been studied for five years around FADs set up between the islands of Tahiti and Moorea in French Polynesia, differs greatly according to the season and time of day (aggregation at night, possibly for security, and dispersion by day, for feeding). This type of behaviour in a given species of fish would need to be studied if it were intended to use artificial reefs to encourage the production of such species.

44. Regarding the assessment of the effects of ARMIs on the ecology in their vicinity, Mr. Bombace suggested the study of stomach contents of predator fish and egg-and-larvae surveys in ARMI zones.

Bio-ecological and Fishing Effects

45. Regarding first the bio-ecological effects, it may be noted that the establishment of an artificial reef (or reef system) leads immediately to the colonization of the surfaces and then, perhaps more slowly, the occupation of cavities and habitats in the structure or between its modules. However, this colonization (of surfaces and of cavities) may differ according to such factors as: latitude (even within the Mediterranean); longitude (e.g., western or eastern side of a major land mass such as Italy); time of the year at installation of the reef; the material of which the reef is composed; the detailed conformation of the modules (the number and variety of cavities and habitats, etc.); the depth of the reef surfaces relative to the sea surface (possible effect of light); the relation of the ARMI site to river or power-plant discharges, or to other major hydrographic features; the relative abundance of the larvae of species that are sessile as adults in the vicinity of the ARMI; the major currents and the minor currents in the vicinity and close proximity, respectively, of the ARMI; the trophic state (eu-, oligo-, etc.) of the area in which the ARMI is established.

46. Nor does colonization necessarily lead eventually to a climax (stable) community, whether sessile or vagile or both (as the two main components of an artificial reef community). There appears to be a process of a random kind at work, with the possible mediation of chemical messengers aimed at favouring colonization by a particular species once a "critical-mass" population has been established, this pioneer colonization in turn possibly attracting later colonists. There may also be a threshhold effect, the actual volume of the ARMI itself being a determinant of a particular type or sequence of colonization under a given set of environmental conditions.

47. Mr Giulio Relini (Italy) presented a study of colonization, using asbestos panels, in relation to the establishment of an artificial reef at Loano. The sequence was quite different from that of the reef system near Ancona, there being, inter alia, no climax predominance of blue mussels (Mytilus galloprovincialis). Different orientations of the panels did not produce substantially different colonization by sessile organisms. There was a tendency towards a colony dominated by bryozoans, in some cases, and by ascideans, in others, depending mainly on the depth (hence illumination and temperature differences) of the panels relative to the sea surface. One surprise result was the action of sea urchins, which completely cleaned the surfaces on which they lived, hence opening up the way for a new period of colonization.

48. Mr Relini's paper is attached hereto as part of Appendix E, together with other scientific contributions presented at various times throughout the Session.

49. Mr G.D. Ardizzone (Italy) related the results of a study of the colonization of an experimental artificial reef set up eight years ago off Fregene, about six kilometres from the mouth of the Tiber. In general, the Tyrrhenian Sea is oligotrophic, but the proximity of the Tiber discharge is probably an important factor. Briefly, the study showed that, although mussels became the dominant species, no climax (stable) community was ever established; the initial predominance of hydroids is considered vital for the later colonization by mussels. The main factor considered to prevent the establishment of mussel dominance is siltation episodes; the mussels are periodically replaced by detritus feeders. The siltation, the locally high productivity of the sea (around Fregene) and the river discharge are antagonistic forces. Dr. Ardizzone's paper is given in Appendix E hereto.

50. Mr Bombace suggested that periodic harvesting of the mussels and other forms of human intervention were probably necessary to prevent the cyclical colonization and thus establish a climax community based on mussels.

51. Mr Morchid (Morocco) strongly supported this view, noting that it is difficult for fish to eat old mussels.

52. Mr Silvano Riggio (Italy) confirmed that, in the region of Sicily and the Ligurian Sea, several factors suggested at the beginning of the present section had been amply confirmed by studies of artificial reefs in these two areas. He noted that although the results obtained around Sicily and in the Ligurian Sea were similar they were quite different from those obtained by Ardizzone (off Fregene) and in the Bay of Naples. He stressed the importance of the three-dimensionality of a structure in determining the colonization pattern and therefore recommended caution in the interpretation of results of studies using essentially two-dimensional panels. He also stressed the importance of the material used to make artificial reefs, materials based on calcium carbonate being generally superior, in respect of colonization, to those based on mineral silicates. Mr Riggio also believed that the overall biological yield of an artificial reef generally reaches a maximum then falls somewhat. Another important role of artificial reefs is, in his view, to facilitate the development of an ecological model of the coastal zone environment.

53. Mr Doumenge (Monaco) stressed the importance of forcing various processes if artificial reefs and mariculture installations are to have the effects desired of them. As examples, he indicated the use of "plastic algae" to promote fixation, and the use of feed (e.g., from sewage-treatment plants, aquacultural wastes) to generate a dynamic reef ecosystem; the choice of forcing factors must, however, be carefully made and studied before being implemented. One can also modify the environment by provoking mini-upwelling or creating circular currents or by introducing restocking specimens.

54. Mr Relini (Italy) stressed the changing nature of thygmotropism: there is the initial existence of the artificial reef itself, then colonization, then, as a rule, the creation of a climax community, then the normal fluctuations in the climax community. Each phase has a different kind of attraction for the thygmotropically motivated fish and shellfish. An important forcing factor is therefore a high diversity of microniches in the reef system.

55. Regarding the fishing effects, as was already noted above, the establishment of ARMIs tends to increase the average individual size of fish in the area in which they are set up. Mr Doumenge (Monaco) explained that, for certain very valuable species (e.g., the Sparidae), ARMIs promote stock stability, especially since some sparid species change sex at least once

during their lifetime; this change is often a reflexion of stock abundance. He also suggested that artificial reefs, to be successful, may have to exceed a threshhold volume (e.g., 50 000 cubic metres) and yet not exceed a maximum limiting volume (say, 80 000 cubic metres). It is necessary to determine such values, at least empirically; however, so far, in the Mediterranean at least, studies are still largely determined not by a sound coastal-zone development policy, as in Japan, but by current availability of funds, facilities and research circumstances in interested institutions. Moreover, a serious fishing effect is not likely to be achieved without a serious programme of massive restocking, which also requires hatcheries. He considered that cage culture, like raft or longline culture was a form of artificial reef with a real fishing effect whether positive (protection of juveniles, increased food supply) or negative (pollution of the sea bed, eutrophication, dissemination of disease, etc.).

56. Mr Lopez Garcia (Spain) informed the Working Party that results obtained so far with artificial reefs in Spain were generally similar to those obtained in Italy.

57. Mr Caddy reminded the Working Party that GFCM had, for many years, been pursuing (through subregional technical consultations, for example) "fishing effects" by many other means, such as the promotion of closed seasons, closed areas, increased minimum mesh size, and so on. ARMIs were simply another tool for improving the fisheries of the GFCM region. Which of these means, and in which combinations, is best, is not yet known. It would therefore be hazardous to be dogmatic about the role of artificial reefs or mariculture installations, separately or in combination.

Relationship Between the Environment, the Artificial Reefs and Mariculture Installations

58. In introducing this Agenda Item, the Chairman noted that the relationship between the artificial reefs and their environment is highly interesting and may lead one to believe that some kind of determinism is at work with respect to the sessile and the swimming organisms.

59. A few examples, some of which had already been evoked in the discussion under Agenda Items 5.2 and 5.3, were elaborated upon by the Working Party. They may be summarized as follows.

(i) The same modules or structures submerged in different environments induce different bio-ecological responses. The colonization of artificial substrates, and the species sequences, are different, depending on whether the reefs are set in rich water (abundant in particulate organic material, phyto- and zoo-plankton) or poor water (oligotrophic). Artificial reefs established in the Adriatic and off northern Sicily are all based on the block (concrete) pyramid design. In the Adriatic, after a phase of very rapid colonization of hydroids, bryozoans, tunicates, and some sponges, there comes a predominant colonization by sestonophagous bivalves, notably mussels and oysters. The phytobenthos is limited to the sporadic occurrence of a few nitrophilic algae (Ulvacea). This climax community can be reached within two years. The food chain is simple: primary and paraprimary (suspended organic particles) production - filter-feeding bivalves - interstitial invertebrates or bivalve seed - carnivorous fishes. The second link (the bivalves) in this chain can already be harvested by man. In the more southerly, oligotrophic waters, which may be rich in particulate matter and

very small plankton (picoplankton), the biological development of the substrates is quite different. Encrusting and arborescent bryozoans, hydroids, tunicates and sponges constitute a phase of long duration. Interstitial species are present, the trophic web is more complex, the phytobenthos is better represented and more diversified, and several species of fish and macro-invertebrates of economic importance live in or around the reefs.

(ii) Different levels are occupied by the different species of reef fish (see the paper entitled "The Reef Fishes" by G. Bombace in Appendix E hereto).

(iii) The same reef types installed in the same environment but in different seasons have a different initial colonization. Installation in spring in the mid-Adriatic is very favourable to hydroids which pave the way for mussel larvae. In contrast, installation in the autumn allows ascidian larvae, such as those of Ciona intestinalis, to predominate, even if the end result is the dominance of mussels; however, this dominance only arises in the following spring. Thus, mussel culture will have lost five or six months.

(iv) In seas in which, during the winter, a thermal inversion occurs between the surface (5-6°C) and the bottom (12-13°C), and especially between the coastal and offshore waters, as is the case in the middle and upper Adriatic, one observes a migration of the majority of species from the coast to the deeper waters offshore; it seems likely that even species associated with reefs migrate offshore in winter. Apart from the apparent thermotropy, the relationship between the oceanographic and ecological characteristics (the environment as a whole), on one hand, and the reef fishes, on the other, constitutes a problem that needs to be solved.

(v) In zones abundant in organic and physical suspended matter (seston and trypton), two opposing forces arise when a reef is installed: sedimentation and bioconstruction, the latter being generally due to sessile and encrusting organisms. The artificial reefs installed in eutrophic zones or subject to currents loaded with terrigenous sediments may be adversely affected by the afore-mentioned antagonism. Intensive sedimentation can cover and choke mussel and oyster beds, for example. In this case, man should intervene and take off the edible organisms (by scraping flat surfaces or cleaning ropes and cables) and, as far as possible, re-establish the conditions prior to the sedimentation.

(vi) In certain coastal areas in the upper and middle Adriatic, especially in summer, one can observe abnormal multiplication of certain species of microscopic algae, pelagic or benthic (diatoms, dinoflagellates, etc.). Some of these (Pennatae diatoms) can produce extraordinary amounts of mucilaginous substances. In the summer, often concomitantly with the abnormal proliferation of algae, vertical stratification of the water column can be observed. Such phenomena can affect the reef zone and its biological production. In particular, the mass of floating mucilage can have an impact on the biotic communities of exposed or suspended surfaces and choke the sessile organisms. A 40% mortality in the mussels on artificial reefs in the Adriatic has been observed this year (1989)

as a result of the mucilage produced during the summer. In contrast, hypoxia can only affect the lower part (50-100 cm maximum) of reefal communities.

PROJECTS COMPLETED, UNDERWAY OR PLANNED

Background and Needs Leading to Projects

60. The Chairman invited participants to indicate, for their respective countries, the main reasons why artificial reefs and mariculture installations had been established. For those countries that had not yet set up such structures, he invited their representatives to indicate, if appropriate, their particular national interest in this field. For Italy, he indicated the following main driving forces:

(i) The need to protect the coastal zone from illegal trawling within the three-mile zone. This protection does, however, affect the fauna of the original soft bottom, generally in a favourable way.

(ii) The possibility of increasing fish production with reef species; however, mariculture installations have the same general objective and effect. There are also the related objectives of repopulation and suspended shellfish culture in association with artificial reefs, which is possible in marine environments rich in primary (phytoplankton) and paraprimary (suspended organic matter) production. If reef zones become widespread in Italy, as they are, for example, in Japan and the USA, the resource-management, socio-economic and, most certainly, political aspects will have to be dealt with.

61. During the 1950s and 1960s, various individual initiatives were taken in Italy but without a serious scientific basis. In the 1970s there were iniatives with some scientific support but nevertheless without a management strategy, whereas in the 1980s a strategy for the management of the coastal zone using artificial reefs emerged which, for the EEC countries, has been incorporated into the regulations on structures No. 2908/83 and 4028/86. (For other historical information, the following reports may be consulted: FAO Fisheries Report No. 357, Rome; G. Bombace, 1989 - Artificial reefs in the Mediterranean Sea. Bulletin of Marine Science, 44(2): 1023-1032; and G. Bombace, 1987 - Iniziative di protezione e valorizzazione della fascia costiera mediante barriere artificiali a fini multipli. LIX Riunione SIPS.)

62. For Spain, Mr. Lopez García reminded the Working Party of Spain's longstanding experience of industrial mussel culture, although this was carried out mainly along the Atlantic coast in fairly well sheltered bays. In the Mediterranean, the primary concern was to protect the marine environment and certain fish stocks, for reasons similar to those mentioned for Italy, and to try to promote inshore fisheries in under-privileged areas. He also believed artificial reefs would be made to play an important role in the field of overall coastal-zone management in Spain. He expressed the fear, however, that very big artificial reef installations might also have an adverse effect on the marine environment; it depended on objectives, and Spain was still at a relatively early stage in testing such systems.

63. Mrs Isabel Moreno (Spain) informed the Working Party that an assessment had been made of the whole coastline of the Balearic Islands, and prospective

sites for the installation of artificial reefs (for the purposes cited by Mr. Lopez Garcia, above) had already been identified. Specific studies of these sites would be undertaken and would be followed up after five and ten years.

64. For Monaco, Mr Doumenge, reminded the Working Party of Monaco's longstanding involvement in the installation and study of artificial reefs as a means of protecting the marine environment, the use of which was and remains primarily aimed at the development of amenities for tourism. However, the study of artificial reefs with a view to developing a model for general use is now being emphasized. Moreover, Monaco is studying the possibility of installing offshore a floating intensive aquaculture farm designed to produce sea bass (Dicentrarchus labrax) - 120 t per year to begin with, rising to 200 t annually. The set-up comprises a containership anchored in a water depth of 300-400 m, which would serve as a fish hatchery and nursery. The juveniles obtained will then be kept in floating cages (of the type used in Atlantic salmon culture) around the ship. This assemblage can be considered truly a kind of artificial reef.

65. For Morocco, Mr Morchid explained that his country was not indifferent to the developments in the field of artificial reefs and mariculture installations. It is specifically interested and active in classical aquaculture and was ready, where appropriate, to set up artificial reefs along the coast, particularly in areas where classical aquaculture was not feasible or appropriate. The main aims are to increase the production of fish and to prevent illegal inshore trawling.

Description of the Artificial Reefs and Mariculture Installations Adopted

66. The Chairman, when introducing this item, noted that all kinds of materials have been used throughout the world to make artificial reefs: stones, tiles, old ships, wrecked cars, tyres, concrete, plastics, etc. These materials have been used in many different ways: to make piles, semi-formal structures and even specific architectures, if the modules allowed it. Several questions remain, however: (i) For what reasons are certain materials used rather than others? (ii) Which materials is it better not to use? (iii) Have the modules used been designed in the light of foreseeable effects? (iv) What is the ideal ratio of modules to space; that is, what density of reef structures is needed to produce an effect on fish production? (v) What is the minimum volume for a reef zone to be properly manageable by professional fishermen?

67. Regarding Italy, after an early experiment lacking scientific support (in Varazze), in which old car wrecks were used, recent experiments have used long-lasting materials (old ships, barges, etc.) and modules (blocks of concrete) that could be assembled according to a specific design. The modules used by IRPEM - concrete cubes - were designed beforehand in the light of certain foreseeable effects (shelter, diversification of habitats, mechanical obstacles, etc.). The volume of the modules used ranges between about 4 000 cubic metres and about 10 000 cubic metres for the various reef zones that have been established. For certain zones in the Adriatic, a "zonal unit" has been adopted which is made up of: 29 pyramids of 5 blocks (4+1); a bed of stones for each pyramid; 12 mussel cages; 116 concrete cylinders to enhance the refuge effect; and a certain number of obstacles provided with hooks. The distance between the pyramids is about 15 m; the 12 mussel cages are placed between the pyramids while the cylinders (4 per pyramid) are placed on the upper surface of the base blocks. Sixteen reef zones have been established so far along the Italian coast as follows: Ligurian Sea - 4; Tyrrhenian Sea - 2; northern Sicily - 2; and Adriatic Sea - 8. The reef zones at Rimini,

Cattolica and Portonovo each contain three "zonal units" as described above. At least ten reef zones are at the project stage and are awaiting funding for their establishment.

68. Mr Piccinetti (Italy) described the principal results obtained in three areas of Italy. In the Fano area since the first efforts were made in 1980, the initial objective was to prevent illegal trawling, for which purpose a barrier of cruciform (three-dimensional) structures was set up enclosing an area of about 16 km long by 2 km wide. Following its establishment, catches by small trawlers operating just outside the protected zone increased by 30%. The fish within the zone are relieved of the stress imposed by trawling and grow more; they migrate outside the zone, however, and are fished by the trawlers. It was later decided that some benthic species living on muddy/sandy bottoms had no substrate in the area on which to lay their eggs. Various experimental substrates were set up. Not only the fish but also some gastropods and cephalopods also laid or fixed their eggs or embryo cases on the blocks. Some pressure for this evolution of a protected area came from the small-scale fishermen themselves. Some positive relationship exists between the size of blocks and the average fish size. In the Ionian Sea off southern Italy, blocks of about two tons each, and some other structures, were also dropped into an area of about 50 km long and 2 km wide. This experiment has been followed up with oceanographic and biological observations, and some experimental fishing. Off Trieste (1 1/2 - 3 miles offshore) mussel culture has for a long time been carried out using surface longlines for raising mussels but they are not optimally suited to offshore locations. Several enterprises using sub-surface longlines (at depths of 3-5 m) have been producing mussels for several years. The results, are generally good; each enterprise produces from 500 to 1 000 tonnes per year. The production in the open sea now is about 5 000 tonnes. The mussels show a good rate of growth: cultivation starting from a size of 2-2.5 cm in spring produces mussels of 6 cm in September/October.

69. The socio-economic conditions of the fishermen exploiting the mariculture sites have improved appreciably. Wherever trawling is banned and blocks are anchored to the sea bed, there is quite a repopulation of fish stocks, and the conversion of fishermen from traditional systems to mariculture is quite rapid.

70. Mrs Silvia Revenga Martinez de Pazos (Spain) briefly described the developments in Spain. While mussel culture off Galicia is based mainly on a system of suspended ropes, longlines are being tried in Catalonia. Proposals for five new ones (2 off Valencia, 1 off the Catalonia coast and 2 in the Canary Islands) have been submitted to the EEC for funding. Two others have already been approved for the Alicante area. Strictly national projects are also being carried out, with two reefs off Valencia and another off the Atlantic coast. Two types of module are being used: one, barrel-shaped and weighing about three tons, is designed to prevent illegal trawling. It has already been observed that it has led to an increase in average individual fish size and that these fish now command an increased price. The other type of module used is cubic. There is some variation in actual size depending on the site under study.

71. The situation in Monaco was described in paragraphs 60 to 65.

OTHER ASPECTS AND PROBLEMS

72. The Chairman informed the Working Party that, for the purposes of Agenda Item 7.1, eight scientific papers would be presented by their respective

authors for discussion by the Working Party. These papers are given in Appendix E hereto. A short summary of the main points raised by these presentation and the subsequent discussion is given in paragraphs 73 to 78 below.

Ecological and Biological

73. The Chairman noted that, during the discussion of Agenda Item 5, the Working Party had seen how the setting up of artificial reefs covers a variety of aspects and problems, relating to the ecology, the biology and the fishery associated with such reefs. Other questions also arise; for example: What is the role of the reef's architecture, the size and assembly of the modules in relation to the specific diversity of the biological populations that colonize the reef? And is this role similar in different seas? What role do the various environmental factors play? For example, effects of currents, eutrophicated water masses, pycnoclines (TSD relationship) on reef or shellfish culture communities. It is known that the unit biomass of mussels in the surface water layer is bigger than that of mussels in deeper water, and this is true for mussels on artificial reefs and on shellfish-culture installations. What role do edaphic factors and the bottom currents play in maintaining the stability of reef modules? Also, aspects of the species biology, the predator-prey relationships, the value of knowing the trophic webs set up by the artificial reefs or mariculture installations where the fish live might be taken into account.

74. The reefs constructed near Ancona in 1987-1988 have been systematically sampled by trammel nets and have shown increases in abundance of certain nekto-benthic fishes, of which Sciaenidae and Sparidae are of particular importance. Direct (scuba) observation around the reef showed a still greater abundance of species attracted than that noted in the experimental catches.

75. The limited information available on stomach contents of fish caught around artificial reefs suggests that a significant proportion of their food comes from areas adjacent to the reef, but further studies on this question are desirable. Experience from trophic investigations of tropical (coral) reefs suggests that a great proportion of foraging activity by reef fish occurs nocturnally in the vicinity of the reef.

76. Evidently, there is a need to quantify the contribution of sedentary reef organisms to the trophic chain leading to finfish production. This is particularly the case for mussels, of which a significant proportion of settlement is lost during growth. Protection from predation of selected surfaces by netting was suggested as one experimental procedure for investigating this phenomenon.

77. What is not yet clear is whether the key role of artificial reefs comes from the trophic contribution or the provision of shelter. It remains to be shown that food limitation is a major constraint, particularly given high current rates of exploitation of commercial species.

78. Experimental mussel culture using suspended ropes has been successfully carried out in the Adriatic; mussels and two species of oysters have been successfully collected and raised to commercial size within one year. Various rope and tray culture methods have been investigated. The rate of return (7 kg of mussels/kg of seed, and 10-15 kg of mussel seed per metre of rope) was satisfactory, despite the slowing down of growth in winter.

Technological

79. The Chairman pointed out that, although considerable advances have been made in the design, production and assembly of artificial reef modules, there was still room for further development and specialization. Although certain ideas about the optimum volume of an artificial-reef were emerging, there are few reliable data on the optimum size, if any, of an artificial-reef system (reef park) or on the optimum density of reef units within a system.

80. Speaking of the Italian (IRPeM) experience, he described the way an artificial reef was set up on the sea bed in such a way as to remain stable for an extended period of time. In particular, the bed of stones is now based on two wire rock cages set close together on the sea floor in a 7 x 7 m configuration. Alignment of blocks is by rods inserted into preformed holes in the base and in the overlying blocks. The operation can be effected relatively rapidly from an appropriate vessel. Mr. Bombace then described a number of features that facilitate the installation and the attachment of mussel-culture lines, which could be taken into account by other institutions entering this field of endeavour.

81. The Working Party noted that over two hundred different kinds of artificial reef and reef modules have been tried and many of these are now available commercially; some have been designed for very precise purposes.

Fishery

82. The main additional information provided related to the methods used for extracting fish from around the reef.

83. In Italy, the gillnet is still the main method of harvesting the fish, whereas cages placed between the reef modules themselves are used for promoting mussel production and the easy removal thereof.

84. In Spain, purse seines are used to take anchovies, whereas longlines are used for larger fish species; trawling and artisanal fishing are carried out in the immediate vicinity of artificial reefs.

85. The Working Party took the view that, while an important function of artificial-reef and mariculture systems was to improve the income of the small-scale fishermen and their communities in the Mediterranean region, it would be appropriate to test other methods, possibly of a more modern and adapted nature, to remove fish and shellfish from a reef. The use of light (as a FAD, prior to capture), sound waves, electric fields, and so on, might open up possible avenues of innovation in this context.

Economic and Social

86. Mr Doumenge (Monaco) contrasted the situation in Japan with that in the Mediterranean. The creation of Exclusive Economic Zones had jeopardized the livelihood of many Japanese distant-water fishermen and a major reconversion problem arose, besides the longstanding shortage of agricultural land. This strongly favoured the development of ARMIs in Japan. In the Mediterranean, the overfishing or degradation (by pollution) of fish stocks, although evident, is not a sufficiently strong economic factor to overcome underlying resistance to a new development in the coastal zone, especially since the role of fisheries in national economies is still very small. He also stressed the

wide range of national situations in the Mediterranean that might or might not favour the development of ARMIs. In particular, he noted that, in France, where there is only a small number of artisanal coastal fishermen, the tendency is towards the use of artificial reefs as a means of promoting sport fishing.

87. A few participants expressed concern about the costing of ARMIs, particularly if only limited objectives were set for their use.

88. Mr. Bombace (Italy) explained that, in IRPeM's experience, the main costs are in the manufacture, transport and installation of the structures. The return on a successful reef system is relatively rapid - two to three years.

89. The Working Party noted that an important element promoting the establishment of ARMIs is the positive effect it has on the social status of the artisanal fishermen, not only in Japan but also in the Mediterranean.

Administrative and Juridical

90. It was recognized that the administrative and juridical situation is rather different in each Member Nation, which makes it difficult to come to detailed conclusions. The Working Party noted, however, that almost everywhere an attempt is made to create artificial reef and open-sea mariculture zones, administrative and juridical obstacles impede he establishment of such installations. In many cases, these difficulties may be due to a misconception of the nature and objectives of these structures. Often, artificial reefs with other purposes than fish production are grouped by the authorities with ordinary mariculture, the latter often being, in turn, as a result of the accidents of social evolution, assimilated into classical agriculture.

91. In practice, some doubt also reigns in the mind of the legislator because authority over the coastal zone often depends on the distance of installations from the shoreline. It is thus not only important to study the juridical situation in each country but also to seek to reduce the juridical and administrative impediments to the creation of reef zones; in other words, to facilitate the emission of permits for the establishment and operation of these reef systems in the framework of an overall policy of the Member Nations of GFCM.

SUPPORTING SCIENTIFIC PROGRAMMES

92. To support scientifically efforts to set up artificial reefs, and especially reefs designed to increase fish production, and indeed any structure in the coastal zone, it is necessary to identify the required research on the environment, the organization of the fisheries, the construction materials, the socio-economic and juridical aspects of the granting of concessions of coastal areas.

93. The research to be undertaken was examined under the following headings.

- **Environmental studies:** Before making major investments in the construction of commercial reefs, it is necessary to determine clearly the hydrographic and sedimentological conditions that are favourable for artificial-reef installations, their geographical location, and the relevant bathymetry. The recommended environmental studies are: hydrography (currents, waves, pycnoclines, thermohaline fronts etc.); hydrobiology (nutrient salts, primary and secondary production,

suspended organic matter, etc.); sea bed (particularly the sedimentology); and the effects of reef and shellfish-culture installations on the environment.

- **Biological studies:** It has been shown that the seasonal state and ecological succession of biotic communities present on various kinds of installations are highly variable; it is not certain, in every case, that this succession will inevitably reach a climax situation. It is desirable to carry out biological and fish sampling in the zone of interest, or parallel sampling in similar experimental zones, before proceeding to set up an artificial reef.

- The growth and mortality rates of commercially important fouling organisms, and their trophic contribution to food webs, should be determined. The rate of recruitment of species such as mussels and oysters to the reef must be monitored at regular intervals; it is also necessary to obtain information on variations in biological diversity and seasonal changes. It is, moreover, necessary to devote more effort to the study of the **colonization of the substrates** offered by the construction materials and modules of reefs by swimming species, their specific diversity and seasonal variations, especially those of commercial importance.

- It is necessary to continue to study the role, potential or real, of artificial reefs and other obstacles in discouraging illegal trawling, and, in particular, their effectiveness in protecting demersal fish communities and inshore nursery areas, as well as the evaluation of biomass by visual techniques. This type of comparative study merits priority in spite of the practical difficulties that this kind of work poses in the field. When reef zones become much more extensive, research aimed at comparing catches in the vicinity of reefs and at a greater distance therefrom can be envisaged.

- **Technological research:** Greater experience must be gained in the installation of artificial structures especially designed for a particular purpose (for example, protection of critical habitats, mariculture, fish aggregation, nursery area) and to disseminate such information to potential users. Criteria of stability of artificial reefs on different types of bottom sediment should be studied first, and appropriate reef models developed. Catch and sampling techniques for reef species should also be improved.

- **Socio-economic considerations:** It is generally necessary to compile documentation on costs of production, transport, upkeep and monitoring of artificial reefs so as, one day, to enable an economic evaluation of artificial reefs to be undertaken.

- It is obsolutely indispensable, from the very beginning, to involve the fishermen in the construction and the choice of site for the installation of a reef if a successful integration of this technology in coastal fishing operations is to be achieved. To facilitate the distribution of sites for the establishment of artificial reef and other installations, it is necessary to study the organization of the fishermen in the zone of interest, the possible conflicts that might arise, the trades concerned, the economic aspects of their activities, etc.

- **Marine parks:** The potential role of artificial reefs, and of any form of aquaculture that may be associated with them, in the protection of coastal areas, along the lines of a biosphere reserve, was examined. It was recognized that the nucleus of absolute protection which should ensure the protection of key biotopes and species should not be subject to any intervention other than the measures aimed at allowing the proper functioning of natural processes. On the other hand, for efficiency, the perimeter of coastal biosphere reserves must enclose several thousand hectares. This implies the need to accompany protection measures by management measures in the buffer zone and, in particular, in a larger transition zone. For the local population to accept indispensable constraints, it must have the benefit of management measures encouraging its involvement in the functioning of the reserve. In this sense, artificial reefs could ensure an increase in renewable resources. Aquaculture techniques that could be associated with the installation of artificial reefs might also provide alternative employment for those that might be affected by the strict regulation required for the protection and functioning of a coastal biosphere reserve.

- **Mariculture:** It was stressed that the present FAO data base on mariculture needs to be improved, especially with respect to mussels and other molluscs of the Mediterranean region. The Secretariat described the measures presently being taken to improve this data base and called on the Member Nations of GFCM to cooperate in this work.

- Among the important pieces of research to be undertaken, the need to study the relationship that might exist between mariculture operations and red-tide episodes observed in the Mediterranean was mentioned. Likewise, the effect of the mucilaginous and biotoxic substances produced by diatoms and other phytoplankton blooms, resulting from the eutrophication of coastal water, must also be studied, particularly from the point of view of the effect of these phenomena on artificial reefs and mariculture installations producing molluscs.

93. The Working Party insisted on the need for a regular financing of research programmes in support of the establishment of new reefs and the development of aquaculture. There certainly exists, outside the Mediterranean and especially in Japan, a considerable amount of experience suitable for encouraging the establishment of new reefs, but the present conditions in the Mediterranean are particular to it; already, appreciable differences between the Adriatic and Tyrrhenian Seas have been observed.

94. In the case of Spain, it was pointed out that, in the context of Regulation (EEC) 4028/86 of the Council, 15% of the investment is devoted to the related research.

PROSPECTS

95. The Chairman explained that, in the long term, the establishment and sustainable operation of reef zones and open-sea mariculture have the objective of developing fisheries, on the one hand, and raising the fisherman's standard of living, on the other. Other objectives have been identified during the discussions; namely, improving coastal-zone management and protection (which also requires better monitoring of sea-water quality).

96. It was stressed that an increased effort is required to improve collaboration and coordination between the various national entities concerned and, more generally, public information on this subject.

97. All this implies a greater awareness and the development of the political will, especially at the national level as well as at the international level.

98. The Working Party was informed of the intentions of the World Bank and of the European Investment Bank to support studies and projects aimed at ensuring the protection of the Mediterranean.

99. Since all these questions directly concern fishing in all its forms, the Working Party expressed its surprise that the GFCM had not, so far, been invited to collaborate in the various studies being carried out by these institutions. It called on the Secretary to contact them with a view to developing appropriate collaboration in fields of common interest. The Working Party also requested Mr. Doumenge to inform the organizers of a seminar on a programme of protection and development of the Mediterranean (Paris, 7-8 December 1989), in which he would participate, of the disquiet expressed by the Working Party in this regard.

100. The observer from the Blue Plan (UNEP) conveyed the wishes of the organization he represented for the success of the session. He indicated that the Mediterranean Action Plan, which was set up in 1975 following the Barcelona Conference on the Protection of the Mediterranean Against Pollution, was engaged in a long-term prospective exercise (2025 horizon) on the essential economic activities in the Mediterranean. This exercise had already lead to the publication of a basic work - The Blue Plan: the Future of the Mediterranean Basin - and a summary thereof containing guidelines for action; a booklet on the prospects for fisheries and aquaculture is in preparation. The various documents underline the importance that could be given to open-sea aquaculture in a context of development in, however, a framework of rational management of the coastal and marine environment. The Blue Plan thus takes a particular interest in this initiative of the GFCM and is pleased to be able to be directly informed of the Working Party's conclusions, by virtue of being represented at this session.

101. The Working Party on Artificial Reefs and Mariculture, which was established by the General Fisheries Council for the Mediterranean at its Nineteenth Session (March 1989), and which met in Ancona from 27 to 30 November 1989, after having discussed the various problems concerning artificial reefs and mariculture installations in the open sea, arrived at the following conclusions and recommendations:

(i) Since complex ecological, technical and socio-economic interactions characterize the creation and management of coastal sites, it is necessary to develop and pursue scientific research by multidisciplinary teams to improve the technology, evaluate the results, and to find ways of optimizing the output.

(ii) Past and present experiments show that only by increasing investments substantially will it be possible to obtain useful results. Basic and applied research should therefore be backed by medium and long-term financing. It is also necessary to find ways to cover the initial costs of installation, and, to this end, request international organizations concerned with the protection and development of the Mediterranean coasts, to devote a part of their budget to this purpose.

(iii) The establishment of artificial reefs must be planned and followed up by scientific research and adequate technological studies.

(iv) The results are linked to the integration of projects within a framework of global coastal management covering vast areas incorporating viable socio-economic units. A minimum level of efficiency calls for adequately large installations.

(v) It is necessary to facilitate administrative and legal steps to be taken in the establishment of artificial reefs and mariculture installations.

102. The Working Group appealed to other international organizations concerned with the development and investigation of the coastal zone, in general, and with artificial reefs and mariculture installations in the open sea, in particular, to collaborate, within the framework of their respective mandates, with the General Fisheries Council for the Mediterranean, in the development of these structures in the GFCM region, in the context of sustainable development and improvement of the quality of the marine environment. It appealed in particular but not exclusively to the International Commission for the Scientific Exploration of the Mediterranean Sea (ICSEM), the United Nations Environment Programme (UNEP), the United Nations Development Programme (UNDP), the Intergovernmental Oceanographic Commission (IOC), the World Bank (WB), the Economic European Community (EEC), the Organisation for Economic Co-operation and Development (OECD), the European Investment Bank (EIB) and the Council of Europe (CE).

103. The Working Group requested the Secretary of GFCM to do all he could, within the limits of his powers, to give effect to the above-mentioned recommendations, and to pursue their implementation, in consultation with the President and Vice-Presidents of the GFCM and with the President of the GFCM Committee on Fisheries Management.

ADOPTION OF THE REPORT

104. The Working Party adopted the Report of its First Session. In doing so, it granted the Secretary the minimum necessary editorial freedom to produce the final version; in particular it requested the Secretary to amalgamate paragraph 90 (introductory suggestions for supporting scientific research) of the Draft Summary Report with paragraphs 93-102 (suggestions for such research agreed by the Working Party) to avoid a repetition of ideas, and to complete sections 10 and 11.

CLOSURE

105. Mr. Lopez García (Spain), speaking on behalf of the participants, expressed his satisfaction with the level and usefulness of the discussions. He thanked the Chairman for his able conduct of the Session, and the Regione Marche and the Istituto di Recerche sulla Pesca Marittima for their kind hospitality in hosting the Working Party's First Session and in providing excellent facilities for the conduct thereof, including the numerous social functions. He also thanked the Secretariat and supporting staff for their effective services.

106. The Chairman responded in similar vein to these kind sentiments.

107. He then asked whether the Working Party wished to express its views on the date and place of its next session. The Working Party expressed the wish

to meet next in 1991; there was, however, no offer, at this time, by one of the national representatives to host the Second Session in his country.

108. The Secretary explained that the Working Group was expected to report first to the Committee on Fisheries Management. He would, however, study the matter carefully with a view to giving effect to the Working Party's wishes, although the Second Session would have to take place after the next session of the Committee which should, in turn, meet some months before the next session of the Council itself.

109. The Chairman declared the Session closed at 18.55 h on 30 November 1989.

ANNEXE/APPENDIX A

Ordre du jour

1. Ouverture

2. Adoption de l'ordre du jour

3. Election du Président et du Vice-Président

4. Organisation de la session, calendrier et documentation

5. Théorie des récifs artificiels et des installations de mariculture

   5.1 Définition
   5.2 Ecologie
   5.3 Effets bio-écologiques et halieutiques
   5.4 Rapports entre le milieu, les récifs artificiels et les installations de mariculture

6. Projets achevés, en cours ou prévus

   6.1 Situation et besoins aboutissant à des projets
   6.2 Description des récifs artificiels et des installations de mariculture adoptés

7. Autres aspects et problèmes

   7.1 Ecologiques et biologiques
   7.2 Technologiques
   7.3 Halieutiques
   7.4 Economiques et sociaux
   7.5 Administratifs et juridiques

8. Programmes scientifiques d'accompagnement

9. Perspectives

10. Adoption du rapport succinct

11. Clôture

Agenda

1. Opening

2. Adoption of the Agenda

3. Election of the Chairman and Vice-Chairman

4. Conduct of the Session, timetable and documentation

5. Theory of artificial reefs and mariculture installations

   5.1 Definition
   5.2 Ecology
   5.3 Bio-ecological and fishing effects
   5.4 Relationship between the environment, the artificial reefs and mariculture installations

6. Projects completed, underway or planned

   6.1 Background and needs leading to projects
   6.2 Description of the artificial reefs and mariculture installations adopted

7. Other aspects and problems

   7.1 Ecological and biological
   7.2 Technological
   7.3 Fishery
   7.4 Economic and social
   7.5 Administrative and legal

8. Supporting scientific programmes

9. Prospects

10. Adoption of the summary report

11. Closure

ANNEXE/APPENDIX B

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ANNEXE/APPENDIX C

Discours d'introduction par le Prof. François Doumenge (Monaco)/
Keynote Speech by Prof. François Doumenge (Monaco)

PROBLEMATIQUE DES RECIFS ARTIFICIELS

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Apparue dans la problématique de l'aménagement des ressources vivantes du littoral dans les années 1960 la notion de récif artificiel n'a cessé de s'élargir au point d'englober maintenant la quasi-totalité des ouvrages d'aménagement de la partie marine de la façade côtière qui est l'objet de l'exploitation artisanale de la pêche et qui est le lieu privilégié de l'aménagement de l'aquaculture.

Une abondante littérature scientifique et technique est maintenant accessible (voir analyse bibliographique) et permet de disposer d'un large faisceau d'informations permettant d'établir un bilan des activités après une vingtaine d'années (1968-1989) de développement.

On peut ainsi constater :

1) Une très inégale répartition des ouvrages et des activités.

A la fin 1989, le Japon dispose de plus de 90 % du volume des structures (20 millions de m^3).

Les USA ont aménagé environ 4,5 % (1 million de m^3) et le reste du monde figure pour le complément (800.000 à 900.000 m^3 dont à peu près la moitié en Méditerranée).

2) Une philosophie scientifique et une finalité socio-économique très diverse.

Pour le Japon il s'agit d'une technique parmi d'autres destinée à fournir une meilleure base structurale à l'activité socio-économique des communautés de pêcheurs artisans vivant dans des villages et organisés en corporations coopératives (Kumiai)qui disposent en pleine propriété du droit de pêche sur un périmètre exclusif attribué par l'état.

Pour les USA, il s'agit d'abord d'un support pour la pêche sportive et aussi par ailleurs d'un système facilitant la réhabilitation de certains habitats.

Pour la Méditerranée et pour de nombreuses autres régions où les implantations restent à l'état expérimental, on recherche une technique permettant d'obtenir une amélioration de la productivité de secteurs côtiers dégradés.

3) Un élargissement du concept de récif artificiel.

Au départ, il s'agissait exclusivement d'épaves immergées puis de constructions en béton organisées pour former un substrat dur sur des fonds meubles. Par la suite la notion de récif artificiel a été étendue à toutes les formes d'interventions humaines modifiant l'environnement littoral aussi bien sur les rivages (enrochements, brise-lames et digues, îles artificielles, etc...) qu'en surface (engins concentrateurs par épaves flottantes artificielles). On peut même considérer l'ensemble des aménagements aquacoles en mer et sur le littoral comme une forme spécialisée de récifs artificiels.

4) Une spécialisation et une extrême diversification des techniques

allant de pair avec la multiplication des finalités : récifs de repeuplement pour les reproductions et les opérations de recolonisation, récifs élevant la productivité par augmentation du taux de survie des juvéniles et accroissement des surfaces, du nombre et de la variété des niches écologiques, récifs de concentration des espèces exploitables facilitant les captures de la pêche artisanale et donc en améliorant la balance économique.

5) La nécessité d'études préalables très fines du milieu

afin d'insérer les constructions dans les mécanismes naturels pour obtenir une élévation du rendement des chaînes trophiques qui peut provenir aussi bien d'interventions mécaniques (upwelling artificiels) que de modifications des conditions géophysiques et d'interventions humaines dans les processus biologiques.

I - LE SYSTEME JAPONAIS

Il est maintenant bien connu dans ses fondements techniques aussi bien par des traductions de documents originaux rédigés pendant la période de haute croissance (1968-1974) et traduits en français (A.D.A. 1983-84) ou en anglais (Aquabio 1982) que par des études de synthèse dans D'ITRI 1985 : contributions de MOTTET M.G., p. 13-112 et GROVE R.S., p. 187-251 et dans Fourth international conference 1989 : contributions de GROVE, SONU et NAKAMURA, p. 984-1103 et YAMANE p. 1038-1040 ainsi que THIERRY J.M., 1988.

L'aboutissement et le développement de la politique d'établissement de récifs artificiels dans le cadre marinovation a été parfaitement exposée par SIMART, 1986.

Les résultats positifs ressentis par les artisans pêcheurs sont aussi bien exprimés par SIMART, 1989.

Il convient de souligner en outre :

1) La poursuite des actions dans un plan de 6 ans (1988-1994) dans lequel la part consacrée au financement des recherches est très sensiblement accrue et qui regroupe comme par le passé les actions d'implantation de récifs artificiels et les opérations de repeuplement et d'aquaculture intensive destinées à augmenter la productivité des eaux et des fonds de la zone littorale.

"Plans de création et de développement des ressources des fonds de pêche côtiers" (Engan Gyogyo Seibi Kaihatsu Jigyo).

Financements prévus en milliard de yen (1 yen = 10 lires italiennes) conversion possible : 1 dollar USA = 125 yen en 1988 140 yen en 1989.

Durée du plan	Récifs artificiels	Aquaculture et repeuplements	Etudes	Total
1976-1982	75	110	15	200
1982-1987	140	200	60	400
1988-1994	140	210	130	480

Il convient de remarquer que ces financements qui doivent suivant les opérations être couverts par 55 % à 65 % de subventions d'états et 45 % à 35 % par des concours locaux (budgets préfectoraux ou communaux, participations des Kumiai) sont des maxima. En réalité les opérations ne peuvent souvent être menées à bien pour absorber la totalité des financements disponibles soit que les études préalables n'aient pu être terminées à temps, soit que les capacités industrielles et logistiques soient totalement saturées et ne puissent répondre à des commandes nouvelles. Les investissements effectifs réalisés dans les dernières années ont été les suivants :

en milliard de yen

	1982	1983	1984	1985	1986	1987
Installation récifs artificiels	15,4	16,0	16,5	17,1	19,4	19,6
Aménagements aquacoles repeuplements	18,3	17,9	17,2	18,6	19,3	18,3
Développement pêche côtière	1,5	1,2	1,2	1,2	1,3	1,3
Total	35,2	35,1	34,9	36,9	40,0	39,2
Pourcentage subvention gouvernement	60	61	62	59	55	55

Pour 1988, une progression sensible a été enregistrée puisque les dépenses totales de la première année du 3e plan ont atteint 48,3 milliards de yen dont 55 % de subventions d'état. Les récifs artificiels (20,5 milliards de yen) et les opérations de repeuplement et d'aquaculture (20,3 milliards de yen) poursuivent leur développement mais un effort tout spécial a porté sur le développement des pêches côtières (dans le cadre en particulier des projets de marinovation) dont le programme a bénéficié de 7,5 milliards de yen.

Le déploiement de ces opérations généralement intégrées dans des plans globaux d'aménagement de l'espace côtier se fait en privilégiant à la fois l'île d'Hokhaido qui a bénéficié de 25 % des investissements pour 5 % de la population de l'archipel et la préfecture d'Okinawa (archipel de Riou-Kiou) qui a fait retour au Japon en 1972 après 27 ans d'administration par les USA et qui a reçu 3,5 % des investissements pour 1 % de la population.

Il faut souligner que l'on ne peut comprendre la politique japonaise de développement des récifs artificiels sans prendre en compte les actions de repeuplement massifs qui lui sont associées.

A cet effet le gouvernement japonais a organisé et assure le fonctionnement de 16 centres spécialisés (carte n° 1) qui sont destinés à fournir les sujets de repeuplement à la fois pour les poissons, les céphalopodes, les mollusques bivalves et gastropodes ainsi que les oursins, et surtout les crustacés. Ces centres sont regroupés dans la "Japan Sea-Farming Association" qui est un office public disposant d'un budget d'environ 2,6 milliards de yen et utilisant les services d'environ 130 spécialistes biologistes marins. Les activités de production d'alevins, de postlarves, ou de naissain intéressent 37 espèces de poissons, 17 espèces de crustacés, et 30 espèces de mollusques et d'échinodermes (Table I). Les repeuplements impliquent la mise en oeuvre de grands nombres de sujets (Table II) seul un effet de masse étant susceptible d'apporter des résultats tangibles.

Dès qu'une filière devient performante et ne nécessite plus de recherches fondamentales et d'expériences d'applications pour la définition des protocoles indispensables à la production de masse les centres nationaux transfèrent leurs opérations à des centres préfectoraux. Ceux-ci à leur tour passeront le relais à des associations locales de producteurs coopératifs qui assumeront la charge des productions de sujets de repeuplement pour les fonds qu'ils exploitent (*).

(*) Un excellent exemple est fourni par le repeuplement en Penaeus japonicus du lac Hamana, préfecture de Shizuoka sur la façade centre Pacifique qui doublant sa production naturelle de 50 T est passé à 100 T en 1988 grâce à des introductions massives de P-L 25-30 chaque printemps. L'opération menée depuis 1976 consiste à organiser une stabulation en filet pendant quelques semaines avant de procéder au repeuplement du milieu naturel. L'efficacité des opérations est venue de l'effet de masse : on est ainsi passé annuellement de 1 à 2 millions de postlarves pour 1976-78 à 5 à 8 millions pour 1979-1982 et enfin 15 à 20 millions depuis 1983. Ces sujets fournis jusqu'à présent par le laboratoire préfectoral de Shizuoka (situé à Numasu) sont produits depuis cette année sur place par une écloserie spécialisée qui a coûté 154 millions de yen en investissements fournis 50 % par l'état, 20 % par la préfecture, 15 % par les collectivités municipales et 15 % par les associations coopératives de producteurs.

II- LE DEVELOPPEMENT AUX USA

Une très abondante littérature (voir analyse bibliographique) permet d'avoir une connaissance presque exhaustive des récifs artificiels organisés aux USA.

En 1986 il existait ainsi pour les zones littorales maritimes 572 emplacements dotés de structures désignés sous le générique de "récif artificiel". Il faut souligner l'imprécision qui résulte de l'extension de cette appellation à des engins destinés à attirer et maintenir l'agrégation de poissons par effet d'épave flottante. 89 emplacements de "Fish Agregating Devices" placés en pleine eau ou flottant en surface entrent ainsi dans la rubrique générale des récifs artificiels. Les aménagements sur le fond sont ainsi au nombre de 483 ce qui est tout de même beaucoup. Cependant il convient de noter que dans ces emplacements le plus grand nombre ont seulement reçu quelques épaves, des pneus usagés, ou des décombres de démolition. Une centaine y ont ajouté des blocs de rochers ou des tuyaux de canalisations en ciment déclassés par malfaçon ou réformés. Seules quelques dizaines de constructions sont véritablement des récifs artificiels suivant la terminologie ou les conceptions en usage actuellement au Japon.

Encore faut-il remarquer que le manque de crédits publics pour les investissements et le désir d'établir une balance positive pour les profits attendus de l'exploitation du périmètre aménagé entraine à rechercher les solutions les moins onéreuses par l'immersion d'épaves. Dans cette perspective les opérations de réutilisation des plates-formes abandonnées après épuisement des gisements côtiers sous-marins d'hydrocarbures (rigs to reefs) paraissent une solution convenable si l'on arrive à trouver le million de dollar que nécessite en moyenne le transport et le mouillage sur un emplacement accessible par la pêche sportive.

En effet c'est presque exclusivement les économies de temps et d'argent procurées par la création d'un champ de pêche à proximité d'un port de plaisance ainsi que les satisfactions données par des prises abondantes de poissons carnassiers de belle taille qui justifient aux yeux des pouvoirs publics l'établissement de périmètres de récifs artificiels.

Ceci explique que ce soit le groupe de pression ayant créé en 1983 le REEFS (Recreational Environmental Enhancement for Fishing in the Seas) qui ait été le support et le promoteur d'une législation fédérale incluant les récifs artificiels (National Fishing Enhancement Act du 8 novembre 1984) suivie par l'application d'un "National Artificial Reef Plan" l'année suivante (STONE 1985).

C'est donc tout naturellement que ce soit au sein du Sport Fishing Institute que l'on ait organisé un "Artificial Reef Development Center" qui a eu la charge de mener et de coordonner la quasi-totalité des études qui ont été consacrées aux récifs artificiels.

L'aspect de développement de récifs artificiels pour la pêche sportive explique que ce soit les côtes du golfe du Mexique avec 211 emplacements et le sud-est Atlantique avec 216 emplacements (McGURRIN 1989) qui aient de loin le plus grand nombre de secteurs organisés en récifs artificiels. Ce sont les Etats de Floride (Contribution de SEAMAN et ASKA, p. 545-561 dans D'ITRI 1985) et du Texas (CROWE et McEACHRON 1986) qui sont de loin les plus actifs et les plus performants. La Louisiane devant intervenir de plus avec le déclassement progressif de ses 3.600 plates-formes pétrolières "offshores" (REGGIO 1987).

Par contre sur la côte du Pacifique les 92 sites de récifs artificiels sont davantage tournés vers le repeuplement et la réhabilitation des fonds grâce à la recolonisation d'algues laminariales sur des supports de structures artificielles (Californie) ou par l'organisation d'un semis de blocs de rochers offrant une grande similitude avec les biotopes naturels. Le Puget Sound (Etat de Washington) a été utilisé d'abord pour l'implantation entre 1979 et 1986 d'une douzaine de périmètres où ont été accumulés à la fois des déblais et des rochers. Puis en mai 1987 on a procédé à l'aménagement d'un ensemble de 14 constructions de 41 m de long, 15 m de large et 6 m de haut, réparties sur une surface de 28.300 m^2 et ayant nécessité l'immersion de 181.400 tonnes de blocs de roches extraits de carrières.

Au total compte tenu des objectifs poursuivis la construction de récifs artificiels semble donner des résultats positifs. Le rythme et l'ampleur des nouvelles constructions dépendra essentiellement de la politique fiscale qui sera appliquée avec des incitations aux investissements privés pouvant bénéficier d'avantages de détaxations ou d'exonérations. Certains Etats sont d'ores et déjà engagés sur une politique à long terme (Floride, Texas, Californie) d'autres semblent devoir les imiter (Louisiane, Caroline du Sud, Washington).

Par ailleurs, les territoires fédéraux aussi bien dans les Caraïbes (Porto Rico - Iles Vierges) que dans le Pacifique (Guam, Micronésie) ont engagé de leur côté des réalisations spécifiques tenant compte des enseignements retirés des expériences menées dans l'Etat d'Hawai depuis 1965. Mais les zones tropicales coralliennes sont semble-t-il moins favorables que les régions subtropicales ou tempérées chaudes.

III- LES EXPERIENCES EUROPEENNES

A partir de 1968 les exemples japonais ont amené à réaliser certaines expériences en Méditerranée : en Italie sur le littoral ligurien et en moyenne Adriatique, en France dans le golfe du Lion.

L'objectif a non seulement tendu à tester des structures et des modules susceptibles d'entraîner des effets d'oasis de peuplement sur des fonds vaseux naturellement pauvres ou sur des fonds ruinés par la surexploitation, mais aussi et surtout d'assurer la protection des frayères et des nurseries littorales contre les ravages des chalutages clandestins.

Les principaux intervenants ont été en France le Cepralmar (organisme régional du Languedoc Roussillon) appuyé par l'IFREMER et en Italie les centres de biologie marine de Ancone, Gênes, Rome et Palerme dont les actions ont été financées par les programmes du Conseil national de la recherche. Les résultats ont été présentés en particulier dans les journées d'études de la C.I.E.S.M. de Cannes en décembre 1982, et dans la consultation technique du C.G.P.M. (FAO) tenue à Ancone en mars 1986 (voir bibliographie).

Un des acquis le plus remarquable a été la démonstration que l'on pouvait passer à des réalisations de mytiliculture suspendue en plein eau aussi bien en Languedoc Roussillon qu'en moyenne Adriatique.

Par contre si les italiens jugent dans l'ensemble que les bilans semblent hautement positifs du côté français, les interrogations persistent quant à l'opportunité de poursuivre les constructions (QUERELLOU et al. 1981 - IFREMER 1987).

CONCLUSIONS

L'exemple japonais doit être situé dans un contexte tout à fait spécifique (ASADA, HIRASAWA, NAGASAKI 1983, NAGASAKI et CHIKUNI 1989, RUDDLE 1987).

Comme le souligne RUDDLE 1987, p. 2 "*Au Japon grâce au système des droits de pêche, le pêcheur artisan a la garantie légale de la disposition exclusive en toute propriété des ressources vivantes des eaux côtieres. Il n'existe pas de différences de concept entre la propriété ou la tenure de la terre agricole et la propriété ou la tenure des fonds marins. Et comme il ressort très clairement du Code civil les activités artisanales de la pêche ont un statut légal identique à ceux des exploitations agricoles.*"

C'est donc par et pour les collectivités villageoises des Corporations de pêcheurs que la création et l'utilisation des récifs artificiels est exclusivement organisée.

Dans ce système de véritable terroir cadastré des fonds côtiers l'artificialisation tend à devenir totale. Comme pour les terres agricoles les champs de pêche vont être progressivement mis en état de produire de plus en plus intensivement des espèces qui font prime sur le marché et dont la vente permettra de soutenir un système sophistiqué et fragile mais profitable. Dans ce contexte l'artificialisation demande un forçage général à la fois par la création de substrats par récifs artificiels spécialisés et par des repeuplements successifs qui leur sont indispensables pour atteindre l'objectif final qui est de maintenir la pêche artisanale en améliorant les conditions de travail du pêcheur et en lui donnant un niveau de vie qui doit être sensiblement supérieur à celui des fonctionnaires ou des ouvriers pour enrayer l'exode rurale et assurer la relève de la vieille génération.

Une telle politique est un transfert social dans une économie de forte croissance et de haut niveau de vie disposant de possibilités considérables par investissements publics maintenant un secteur de travaux publics dont les activités sont un des piliers essentiels de l'économie.

Transférer ce système hors du Japon ne semble guère concevable.

Par contre on peut en retirer l'enseignement que :

1) L'efficacité et le rendement d'un ensemble de récifs artificiels dépend de son insertion dans un système global ;

2) pour pouvoir valoriser les récifs artificiels sur le plan socioéconomique il convient de faire bénéficier les pêcheurs artisans d'un cadre juridique les assurant du contrôle et de la gestion du système en leur en confiant la responsabilité et en leur en laissant la charge et les profits.

Par ailleurs si l'on observe ce qui s'est passé un peu partout aussi bien au Japon, qu'aux USA, en Méditerranée, et dans de nombreuses régions tropicales, il ressort que les performances des récifs artificiels sont étroitement liées aux conditions de l'environnement et au fonctionnement des systèmes naturels.

Les milieux eutrophiques offrent un environnement favorable car leur instabilité résultant du forçage naturel qu'ils subissent entraîne le déclenchement d'une active colonisation de couverture dont la densité monospécifique fournit la base à de nouvelles chaînes alimentaires et permet d'obtenir des productions aquacoles grâce aux mollusques filtreurs. Les secteurs les plus potentiellement favorables aux ensembles de récifs artificiels sont donc tout naturellement ceux liés à des complexes deltaïques (Pô, Rhône, Ebre, Mississippi) ou ceux bénéficiant de facteurs hydrodynamiques d'upwelling (Californie) ou de convergences de dérives de surface Oya-shio et Kuro-shio sur la façade Pacifique du Japon, courant de Tsushima en mer du Japon, Gulf Stream sur la côte du sud-est Atlantique des USA, etc...

Par contre, les eaux oligotrophes ne pourront être réceptives que si l'on parvient à y induire des phénomènes hydrodynamiques apportant des retours en surface des eaux de profondeur ou si l'on peut y injecter des effluents externes ou si l'on parvient à établir de nouvelles chaînes alimentaires grâce à une diversité spécifique qui bien souvent diminue la productivité par des impasses.

Il convient de remarquer que le mécanisme d'endo-upwelling qui semble déterminer le développement des récifs coralliens comme de véritables oasis dans un océan oligotrophe (ROUGERIE, WAUTHY et al. 1986-1988) explique que dans un tel système l'adjonction de récifs artificiels ne pourra pas déclencher des phénomènes entrainant une augmentation de productivité et que l'on devra se contenter d'effets concentrateurs ou de protection.

En définitive la stratégie d'implantations de structures de récifs artificiels exige pour apporter des résultats positifs une connaissance très fine des phénomènes physico-chimiques, hydrodynamiques et biologiques qui caractérisent l'environnement dans lequel on souhaite intervenir. L'originalité du milieu côtier imposera dans tous les cas une adaptation cas par cas des volumes, des formes, des matériaux, etc...

Seules l'habileté et l'aptitude des concepteurs et des réalisateurs à se plier à ces exigences pour en retirer des avantages pour la pêche ou l'aquaculture permettra de procurer une augmentation des rendements et des revenus justifiant des investissements collectifs coûteux.

Enfin seule l'insertion des recherches et des réalisations dans un ensemble socioéconomique cohérent capable de structurer les activités d'exploitation apportera la garantie de durée et de continuité indispensable à cette forme d'aménagement du littoral.

ANALYSE BIBLIOGRAPHIQUE

Les problèmes relatifs aux récifs artificiels ont été l'objet d'une masse considérable de publications de tous ordres. Il ne saurait donc être question d'en présenter une bibliographie classique traitant du sujet.

La présente analyse a pour but de permettre aux lecteurs de langue anglaise ou française de disposer des sources essentielles accessibles dans une bonne bibliothèque spécialisée en océanologie.

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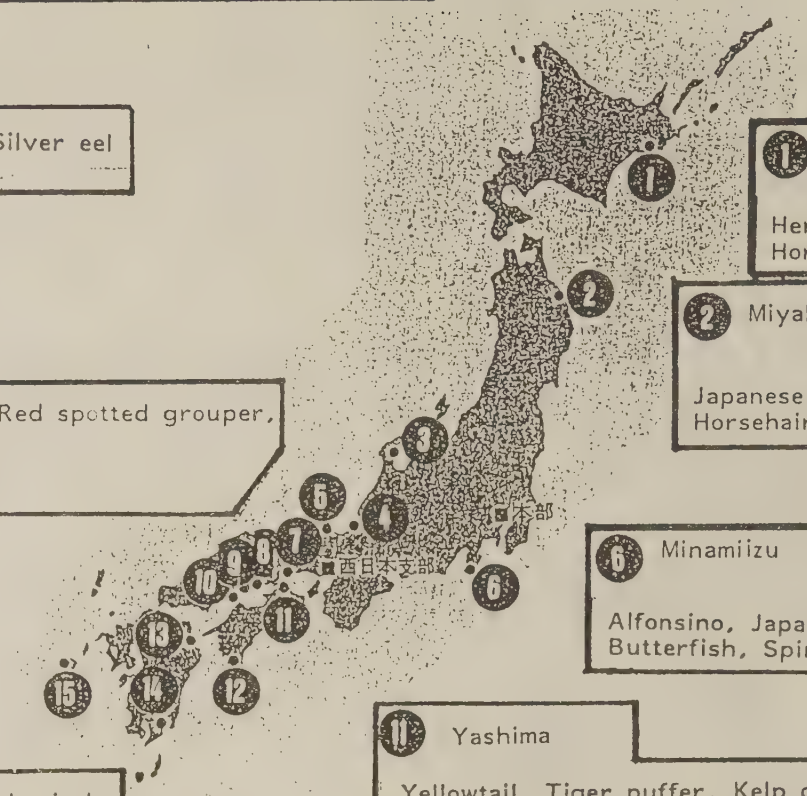
3	Notojima	Dab, Sandfish, Cod, Pandalid shrimp
4	Obama	Willowy flounder, flathead dab, tanner crab, pandalid shrimp
5	Miyazu	Red tilefish, Roundnose flounder, Arrow squid

Fig. 1.- Implantation des laboratoires nationaux de "Japan Sea Farming Association".

(Espèces faisant l'objet de production massive)

1 Tamano

Swimming crab, Mangrove crab, Silver eel
`ctopus, Red-spotted grouper



1 Akkeshi

Herring, Barfin flounder, Slime founder, Horsehair crab, Hanasaki king crab

2 Miyako

Japanese flounder, Jacopever, Herring, Horsehair crab, Slime founder

8 Hakatajima
9 Momoshima
10 Setoda

Japanese founder, Red seabream, Red spotted grouper, Devil stinger, Octopus

6 Minamiizu

Alfonsino, Japanese seabass, Japanese bluefish, Butterfish, Spiny lobster

11 Yashima

Yellowtail, Tiger puffer, Kelp grouper, Octopus

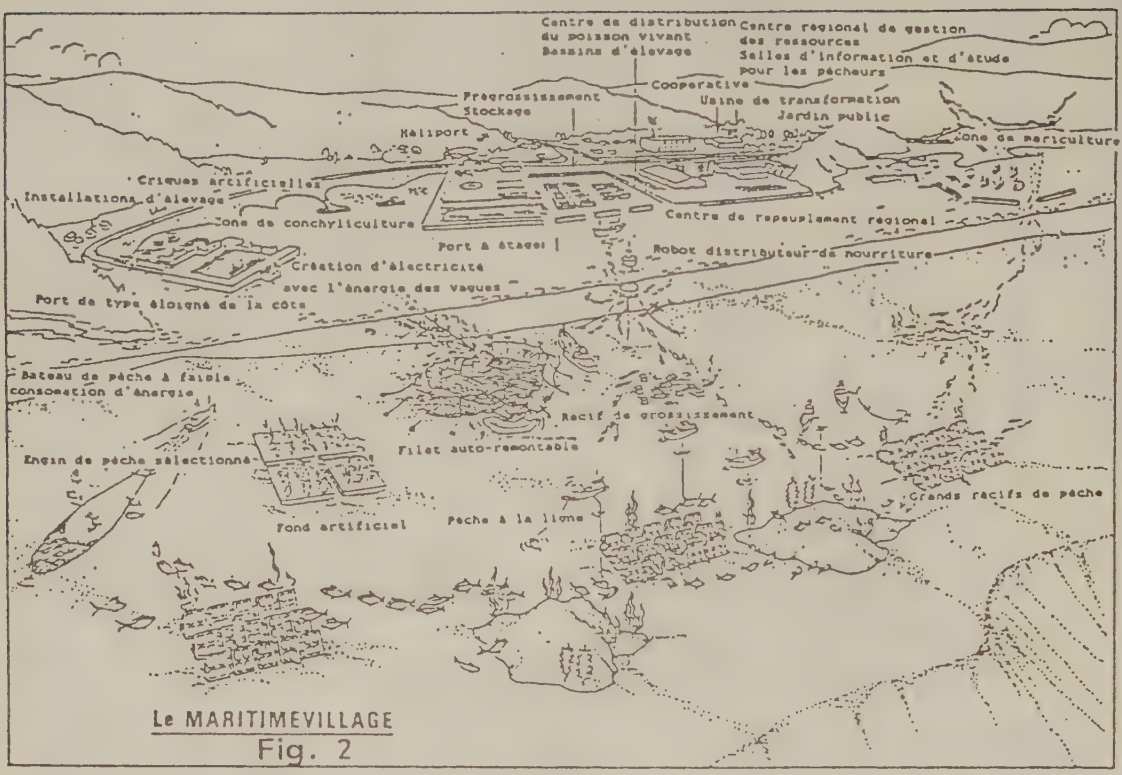
15 Cotou

Yellowtail, Striped jack, Yellow amberjack, Squid, kelp grouper

16 Ishigaki

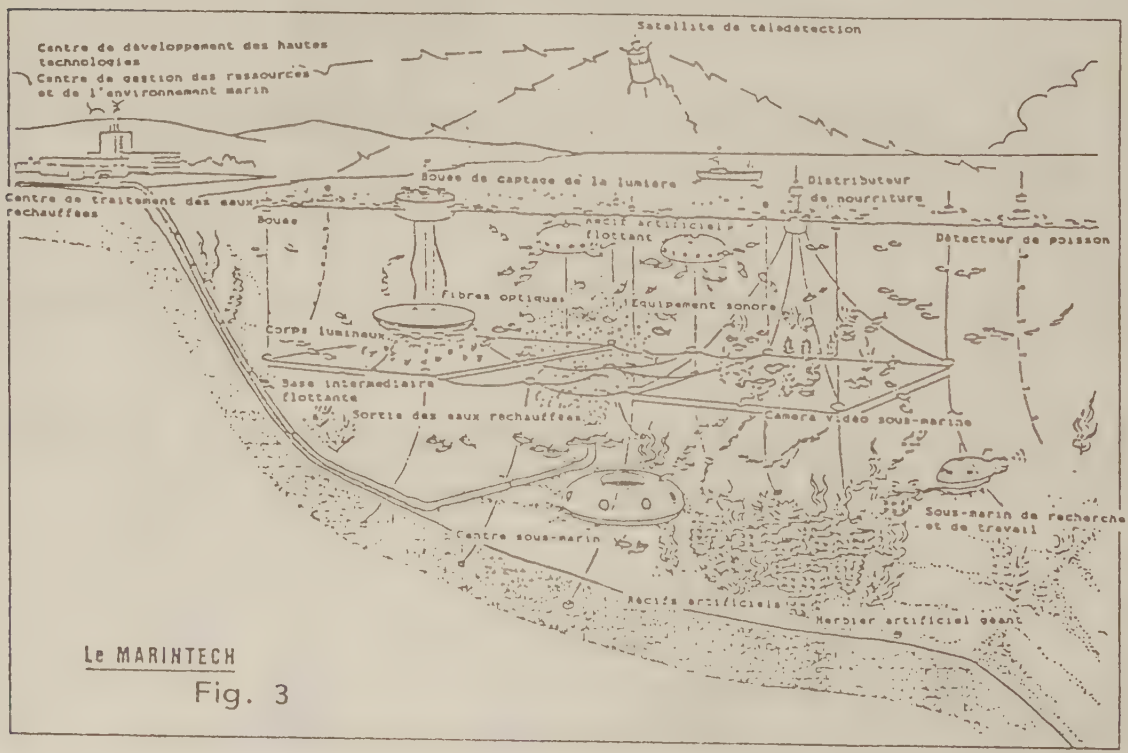
Tunas, Amberjacks, Groupers, Blue Fusilier, Mangrove crabs, Giant Cuttlefishes

12	Komame	(Brooding) Striped jack, Yellowtail, Kelp grouper
13	Kamiura	Striped jack, Yellowtail, Red Seabream, Silver eel
14	Shibushi	Kuruma prawn, Swimming crab, Yellowsea prawn, Horseshoe, Flog crab


Centre de distribution du poisson vivant Bassins d'élevage
Centre régional de gestion des ressources Salles d'information et d'étude pour les pêcheurs
Coopérative
Usine de transformation Jardin public
Progressivement Stockage
Héliport
Zone de mariculture
Criques artificielles
Installations d'élevage
Zone de conchyliculture
Centre de repeuplement régional
Port à étages
Robot distributeur de nourriture
Création d'électricité avec l'énergie des vagues
Port de type éloigné de la côte
Bateau de pêche à faible consommation d'énergie
Récif de grossissement
Filet auto-remontable
Engin de pêche sélectionné
Grands récifs de pêche
Fond artificiel
Pêche à la ligne

Le MARITIMEVILLAGE

Fig. 2



Le MARINTECH

Fig. 3

Table 1. Production of fingerlings in Japanese Sea Fisheries Association (1988)

Taxis	Category: Family name	Scientific name	Common name: English name	Japanese name	Fingerling production (×1000)	Size(mm) or stage
Pieces	Clupeidae	*Clupea pallasi*	Herring	Nishin	847	TL* 31 to 70
	Gadidae	*Gadus macrocephalus*	Cod	Madara	4	TL 30
	Carangidae	*Caranx delicatissimus*	Striped jack	Shimaaji	821	TL 23 to 35
		Seriola aureovittata	Yellow amberjack	Hiramasa	142	TL 33
		S. dumerili	Amberjack	Kanpachi	1	FL* 35 to 41
		S. quinqueradiata	Yellowtail	Buri	1,934	TL 24 to 32
		S. rivoliana	Longfin amberjack	Hirenagakanpachi	+*	FL 41
	Serranidae	*Epinephelus akaara*	Red spotted grouper	Kijihata	134	TL 29 to 42
		E. microdon	Black rock grouperm	Madarahata	+	TL 30
		Plectropomus leopardus	Blue spotted grouper	Sujiara	+	TL 30
	Sparidae	*Pagrus major*	Red seabream	Madai	4,132	TL 18 to 84
	Trichodontidae	*Arctoscopus japonicus*	Sandfish	Hatahata	227	TL 37
	Scombridae	*Scomberomorus niphonius*	Spanish mackerel	Sawara	20	TL 35
	Scorpaenidaes	*Sebastes schlegeli*	Jacopever	Kurosoi	613	TL 35
	Synanceiidae	*Inimicus japonicus*	Devil stinger	Oniokoze	10	TL 18
	Paralichthyidae	*Paralichthys olivaceus*	Japanese flounder	Hirame	6,224	TL 18 to 76
	Pleuronectidae	*Eopsetta grigorjewi*	Roundnose flounder	Mushigare	61	TL 13 to 33
		Hippoglossoides dubiuso	Flathead dab	Akagarei	12	TL 25 to 29
		Limanda herzensteini	Dab	Magarei	446	TL 20
		Microstomus achne	Slime flounder	Babagarei	23	TL 22 to 34
		Tanakius kitaharai	Willowy flounder	Yanagimushigarei	9	TL 26 to 34
		Verasper moseri	Barfin flounder	Matsukawa	51	TL 24 to 25
	Tetraodontidae	*Takifugu rubripes*	Tiger puffer	Torafugu	195	TL 22
Crustacea	Penaeidae	*Penaeus japonicus*	Kuruma prawn	Kurumaebi	98,100	TL 14 to 41
		P. olientalis	Yellowsea prawn	Kouraiebi	959	TL 22
	Pandalidae	*Pandalus borealis*	Deep sea prawn	Hokkokuakaebi	2	TL 17
		P. hypsinotus	Coonstripe prawn	Toyamaebi	179	TL 10 to 16
	Portunidae	*Portunus trituber-culatus*	Swimming crab	Gazami	11,770	C 1 to 2*
		Scylla tranquebarica	Mangrove crab	Nokogirigazami	199	C 1
		S. oceanica	A kind of M.c.	Amimenokogirigazami	676	C 1
	Lithodidae	*Paralithodes brevipes*	Hanasaki king crab	Hanasakigani	9	C 1
	Atelecyclidae	*Erimacrus isenbeckii*	Horsehair crab	Kegani	544	M
	Majidae	*Chionoecetes opilio*	Tanner crab	Zuwaigani	+	C 1
Mollusca	Ostopodidae	*Octopus vulgaris*	Octopus	Madako	5	S* 14 to 21
	Loliginidae	*Sepioteuthis lesso-niana*	A kind of squid	Aoriika	1	ML 7
		Doryteuthis bleekeri	Arrow squid	Yariika	2	ML 10 to 12
	Sepiidae	*Sepia latimanus*	Giant cuttlefish	Kobushime	1	ML 30

* Remarks: TL → Total length, FL→ Fork length, + → <444, C.1 → The first crab stage, M → Megalopa stage, S → Number of suckers, ML → Mantle length

Table 2. Main species restocked in Japanese coastal waters (>One million individuals's species: 1986 fiscal year) Exception; anadromous, amphidromous fishes and freshwater species)

Taxis	Category: Family name	Category: Scientific name	Common name: English name	Common name: Japanese name	Fingerling production (×1000)
Pieces	Carangidae	*Seriola quinqueradiata*	Yellowtail	Buri	1,722
	Labridae	*Halichoeres poecilepterus*	A kind of labroidfish	Kyuusen	3,165*
	Sparidae	*Acanthopagrus schlegeli*	Black seabream	Kurodai	5,829
		Pagrus major	Red seabream	Madai	17,248
	Hexagrammidae	*Hexagrammos otakii*	Fat greenling	Ainame	1,116*
	Paralichthyidae	*Paralichthys olivaceus*	Japanese flounder	Hirame	5,860
Crustacea	Panaeidae	*Penaeus japonicus*	Kuruma prawn	Kurumaebi	306,882
		P. semisulcatus	Green tiger prawn	Kumaebi	3,699
		Metapenaeus monoceros	Speckled shrimp	Yoshiebi	25,350
	Portunidae	*Portunus trituberculatus*	Swimming crab	Gazami	30,067
Mullusca	Haliotidae	*Nordotis discus*	A kind of abalone	Kuroawabi	7,018
		N. d. hannai	A kind of abalone	Ezoawabi	12,029
		N. gigantea sieboldii	A kind of abalone	Megaiawabi	2,219
	Buccinidae	*Babylonica japonica*	Marine snail	Bai	5,936
	Arcidae	*Scapharca broughtoni*	Ark shell	Akagai	1,834
	Pteriidae	*Pinctada fukta*	Japanese pearl oyster	Akoyagai	2,000*
	Pectinidae	*Patinopecten yessoensis*	Ezo giant scallp	Hotategai	2,192,170*
	Ostreidae	*Crassostrea gigas*	Japanese oyster	Magaki	5,969
	Veneridae	*Meretrix lusoria*	Common hard clam	Hamaguri	3,073*
		M. lamarckii	Shield clam	Chosenhamaguri	1,879
		Tapes philippinarum	Short-necked clam	Asari	22,529,432*
	Mactridae	*Mactra chinensis*	Hen clam	Bakagai	135,866
		Spisula sachalinensis	Northern clam	Ubagai	17,234*
		Tresus keenae	Gaper	Mirukui	8,000
Echinoidae	Strongylocentrotidae	*Strongylocentrotus intermedius*	A kind of sea urchin	Ezobahununi	6,843
		S. nudus	A kind of sea urchin	Kitamurasakiuni	5,347*

Remarks: * Mosity natural seed

ANNEXE/APPENDIX D

Contributions scientifiques données pendant la session/
Scientific Papers delivered during the session

Auteurs/Authors	Titres des contributions/Titles of Papers
1. Arculeo, Marco; Bombace Giovanni; D'Anna, Giovanni; Riggio, Silvano	Evaluation of the fishing yields from a protected and an unprotected coastal area of NW Sicily
2. Bombace, Giovanni	Les poissons récifaux
3. Bombace, Giovanni; Fabi, G.; Fiorentini, L.	Preliminary analysis of catch data on artificial reefs in Central Adriatic
4. Fabi, G.; Fiorentini, L.	Shellfish culture associated to artificial reefs
5. Relini, Giulio; Cormaggi, P.	Colonization patterns of hard substrata in the Loano artificial reef (Western Ligurian Sea)
6. Relini, Giulio; Orsi-Relini, Lidia	Artificial reefs in the Ligurian Sea: a report on the present situation
7. Relini, Giulio; Relini, M.; Torchia, G.	Fishes of the Loano artificial reef
8. Riggio, Silvano	A short review of artificial reefs in Sicily
9. Riggio, Silvano	Zoobenthic colonization of a small artificial reef in southern Tyrrhenian: results of a three-year survey
19. Toccaceli, M; Levi, Dino	Preliminary data on an experimental trammel net survey designed to estimate the potential of a planned artificial reef near Mazzara del Vallo (Italy)

EVALUATION OF FISHING YIELDS IN A PROTECTED AND AN UNPROTECTED COASTAL AREA OF N/W SICILY

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KEYWORDS - Artificial reefs, fish, fisheries, Sicily.

ABSTRACT - The results are reported and critically discussed of a fishing survey carried out over one year on two nearby bottom grounds, one of which was part of a zone sheltered with artificial reefs. All the results obtained show an improvement of the catches in relation with the reef shelter. A fishing survey aimed at evaluating of demersal resources was carried out in a coastal area of the Gulf of Castellammare, NW Sicily. Constantly higher fishing yields were obtained inside a zone sheltered with concrete boulders and scattered with small artificial reefs. A greater body size for some of the most common edible fish was also recorded. Comparison of fish communities also showed the immigration into the reef zone of resident fish and crustacea related to hard rocky substrata. Examination of gut contents of **Diplodus annularis** showed the presence of organisms related to the boulders. Attraction to the substrata, availability of food items and shelter were identified as the factors underlying the success of the reef.

INTRODUCTION - Of the many possible undertakings aimed at improving biological resources in the coastal zone, the construction of artificial reefs is perhaps the only one well agreed upon by the vast majority of professional fishermen. The economic benefit to artisanal fisheries expected from curtailing of nearshore trawling has promoted the demand for the building of artificial reefs.

The demand is even more compelling in those sites where the conflict between trawlers and artisanal fishermen has risen to a highly dangerous level: among these areas are the southern coast of Sicily and the Tyrrhenian coast east of Palermo.

Nevertheless the installation of mechanical deterrents to curb trawling has been episodic. Long administrative procedures and the high costs or the uncertainties about the mechanisms involved in the enhancement of fishing production have prompted caution in the promotion of the initiative. Plans for the installation of artificial reefs along the coasts of Messina (East Sicily), Agrigento - Ragusa (South Sicily), and Marsala (West Sicily) are under way.

The only reefs hitherto built in western Sicily are located in the Gulf of Castellammare. According to local people, their establishment has coincided with a measurable increase in fishing yields as well as a diversification of the catches. Data on the outcome of reefs are however based more on

bionomic investigations than on fishing surveys; this shortcoming makes a close evaluation of the actual effects of reefs little reliable.

A survey promoted by Palermo Province ("Progetto Mare") on the feasibility of artificial reefs along the coast of Palermo gave us an opportunity for an approach to either the description of the benthic colonization or to the evaluation of fishing yields in relation to natural and man-made substrata. A yearly series of samplings made on an unprotected fishing ground and on a nearby area sheltered with concrete boulders allowed us to attempt an **a posteriori** estimate of the efficacy of man-made reefs.

DESCRIPTION OF STUDY AREA - The area under examination is the shallow coastal bottom stretching from Balestrate to Trappeto (38°3'5" North Lat, 13°2'8" East Long from Greenwich. See IIM nautical map 1:100.000 no. 17; IGM Maps 1/25.000, F. 249 III S.O.), about in the central coastal section of the Gulf of Castellammare (Fig. 1, 2).

A **Posidonia oceanica** meadow once occupied the gently sloping plain, with limited breaks in the biotic continuum occupied by patches of bare sand and mud and **Cymodocea nodosa** tufts growing off the outflows of small streams.

Over the past twenty years the area of our survey, as well as the whole central and eastern sector of the Gulf, has been subjected to a heavy environmental disturbance which has sensibly worsened in the last decade, thus altering the primitive environment; a major effect has been the disappearance of the luxuriant **Posidonia** which reduced to isolated tufts overgrown with epiphytes.

Mismanagement of the minland and the coastal zona and use of the bay as a sink for a variety of refuse (or disposal of every kind of waste into the sea) sea have made the Gulf of Castellammare one of the most endangered coastal biotopes in Sicily.

In addition to chemical pollution and eutrophication, nearshore trawling is also responsible for the overfishing first pointed out by ARENA et BOMBACE (1971) and recently confirmed by ARCULEO **et al.** (1988).

The ecological disturbance is primarily consequent to the outlets and the disposal of solid wastes by olive oil plants and other small factories. The largest contribution to water pollution is however due to three major alcohol distilleries from wine overproduction in western Sicily and to wastes from dregs of pressed grapes.

Domestic untreated effluents from the towns and runoff from agricultural land add to the pollution burden. A persistent deposition of solid organic detritus occurs on the shallow bottom nearshore, thereby giving place to extensive layers of decaying litter which may grow into littoral banks over 1m thick. Both the outflows and the decaying organic

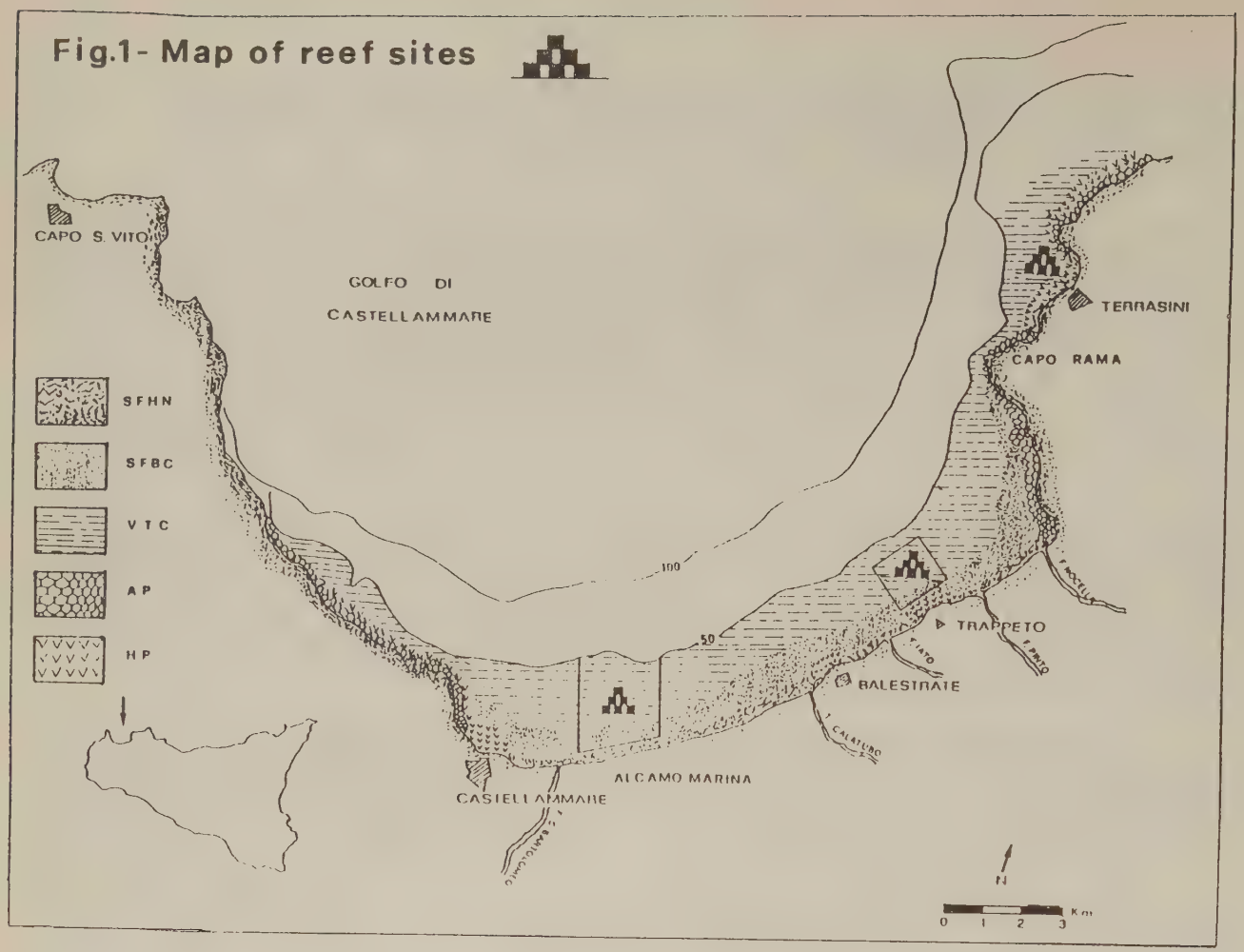
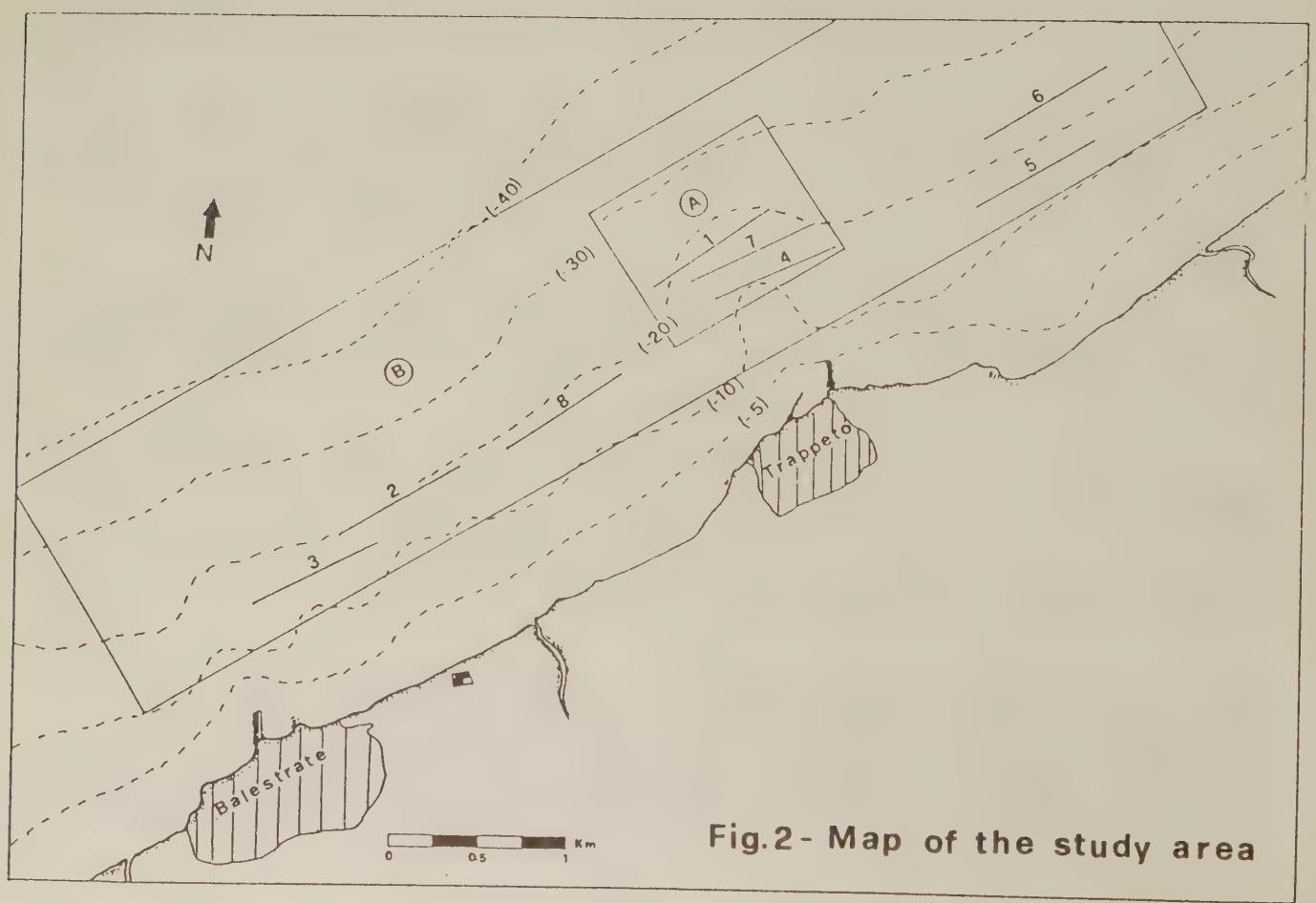


Fig.1- Map of reef sites
CAPO S. VITO
GOLFO DI
CASTELLAMMARE
TERRASINI
CAPO RAMA
SFHN
SFBC
VTC
AP
HP
100
50
TRAPPETO
BALESTRATE
ALCAMO MARINA
CASTELLAMMARE
N
0 1 2 3 Km


N
(-40)
(-30)
(-20)
(-10)
(-5)
A
B
1
7
4
8
2
3
6
5
Trappeto
Balestrate
0 0.5 1 Km
Fig.2- Map of the study area

matter have in a few years brought about the dying off of the primitive benthic associations thereby favouring selective encroachment of the newly available solid substrata by populations of filter feeders.

Extensive mussel beds and reef - like "hermelles" made up by the sedentary polychaete worm **Sabellaria alveolata** have, since the late seventies, colonized the hard and soft substrata attaining a -10m depth (D'ANNA **et al.** 1985, 1989). The **restocking area** stretches over about 1000 hectares. The fishing ground is a gently sloping soft bottom of fine sand and mud. Its limit shoreward is marked by a rocky slope 1m high lying at a depth of about -12m.

Fine sediments make a thin cover with scattered tufts of **Cymodocea nodosa**. A very intense silting rate, partly due to resuspended of organic and clayey particles, causes a persistent turbidity which restricts the normal underwater visibility to only a few centimets.

In such conditions only the 3 following major benthic communities are reported (Fig. 1):

a) the **SFS** biocoenose **(Fine sands in shallow water of the surf zone)**, including wide reef-like "hermelles" of **Sabellaria alveolata;**
b) the **SFBC (Fine, well sorted sands)** biocoenose, including the **Cymodocea nodosa** "lawn" ("pelouse" after PERES et PICARD, 1965) thriving on the sediment layers between the outflows of freshwater streams;
c) the **Posidonia oceanica** meadows restricted to the soft bottoms off Balestrate and Trappeto to a depth of about 10m.

At lower depths the fine sands are enriched with organic mud and clay. The colloid content increases regularly moving from the coastside, and gives place to an even, compact ground layer. Below -20m the benthic associations referred to as **biocoenoses of terrigenous coastal muds (VTC)** are met with.

MATERIALS AND METHODS - Eight sampling sites were randomly chosen in the area, three of which inside the **restocking ground** (Fig. 2). Single sampling sites were first treated as subsampling stations. Homogeneity of the collected data proved the existence of two distinct fishing zones lying respectively inside and outside the reef area. The samplings made in the ground zone between the pyramids and the outer row of boulders were grouped into a single station and referred to as **A.** The adjacent unprotected area was referred to as **station B,** included the grounds to the left and right of **station A.**

Fishing was performed by trammel net. Four samples per month were collected from both grounds over one year. The total number of samples was 41; limitedly at the **station** B sampling in December and January was prevented by the rough sea. Length of the net was 800m; height 1.8m; bar mesh size 40mm.A wooden boat 4.8m in length equipped with an outboard engine was used. The trammel net was hauled at dusk to a mean depth of -18m and weighed at sunrise: it was therefore left in place for about 12 hours. Individual fish were identified to the species level; whenever possible, their biomasses and weights were recorded,

together with sex ratio. Body size of the most prized species was recorded, too. Data collection and analysis was based on standard procedures. Care was taken in making close comparison between both fishing grounds feasible. A study of the gut contents of 54 individuals of **Diplodus annularis** collected from **station A** was also carried out. The methods employed are those described by HUREAU (1970) and ROSECCHI (1987).

RESULTS - Seventythree species were identified in the fishing samples, included in the following taxonomic groups:
Fish, 48 species, equal to 65.7 % of the total;
Crustacea, 11 species, equal to 15.1 %;
Mollusca, 12 species, equal to 16.4 %;
Echinoderms, 2 species, equal to 2.8 %;

As many as 62 species were reported from **station A** and 53 from **station B**, corresponding to 82% and 72% of the total species composition respectively (Table 2). Differences were found in the number of fishes (39/33) and Mollusca (12/9). Even greater differences characterized the biomasses: the yield was 47.9kg at **station A** and 26.6kg at **station B**, 64.3% and 35.7% of the total, respectively. Mean value of catch was 2.5kg in **A** and 1.2kg in B (Table 2). Mean monthly catches are reported in Fig. 3. Higher values were constantly obtained at **station A**, with a maximum in February, mostly consisting of cuttle fish and breams. Peaks in the catch at station B appeared in May and October. Mean monthly catches in both station and % composition in wet weight are illustrated in Figs. 4 to 7.

Among the prey restricted to **station A** were highly prized species such as bass (**Dicentrarchus labrax**), breams (**Diplodus spp.**), the scorpion fish (**Scorpaena porcus**) and marine crayfish, **Palinurus elephas.** On the contrary, the species exclusive of **station B** were of little or no economic value at all (Table 3).

Examination of body size in **D. annularis** shows a prevalence of larger individuals at **station A**. The contrary is evident for **Pagellus erythrinus**. Station. A is however characterized by the presence of individuals belonging to a complete suiccession of size classes (Figs. 8 and 9). Results of an analyse of the gut contents of 54 specimens of **D. annularis** are reported in Table 4. Algae, Coelenterate Hydroidea, Amphipod Crustacea, Polychaete worms and Bryozoa are the most frequent groups. The crustacea make up the highest biomasses.

DISCUSSION - The most remarkable aspect revealed by our survey is the constantly positive results either in species richness or in biomass and individual body size - and therefore in economic value - obtained inside the sheltered area at **station A.** Constancy is evidence of a favourable effect brought about by artificial reefs upon the fishing yields and potential fish production.

The positive results however do not make it clear whether biological productivity is actually enhanced or whether the higher yields are merely a consequence of the thygmotropism induced by the boulders. A further effect which may account for the most relevant increase in the catches at **station B** is the severe constraint posed by the barrier of boulders to illegal trawling, which greatly contributes to the impoverishment of the

TAB. 1 - LIST OF SPECIES COLLECTED IN THE STUDY AREA

		STATION A		STATION B	
	FISHES	N°	W (g)	N°	W (g)
	Torpedo torpedo (L.)	1	378	2	1409
	Torpedo marmorata Risso	4	1531	0	0
*	Nettastoma melanurum Raf.	0	0	1	292
*	Merluccius merluccius (L.)	4	291	1	110
*	Mugil cephalus L.	5	3200	1	598
*	Sphyraena sphyraena (L.)	2	350	1	358
*	Dicentrarchus labrax (L.)	1	3300	0	0
	Serranus scriba (L.)	1	70	0	0
*	Dentex dentex L.	1	82	4	456
*	Sparus pagrus L.	13	1160	7	412
*	Pagellus erythrinus (L.)	22	2041	14	769
*	Pagellus acarne Risso	28	508	19	281
*	Lithognathus mormyrus L.	34	3283	31	2629
*	Diplodus annularis (L.)	172	7207	56	3426
*	Diplodus sargus (L.)	4	857	0	0
*	Diplodus vulgaris (E. Geoff.)	5	85	3	216
*	Diplodus puntazzo (Gm.)	1	30	0	0
*	Boops boops (L.)	3	351	3	396
*	Boops salpa (L.)	1	82	0	0
*	Spondyliosoma cantharus (L.)	2	146	0	0
*	Spicara maena (L.)	1	103	0	0
*	Spicara smaris (L.)	5	507	1	182
*	Mullus barbatus L.	1	45	3	114
*	Mullus surmuletus L.	21	2256	4	409
*	Corvina nigra L.	2	1219	0	0
*	Trachurus trachurus L.	2	310	1	7
*	Trachinotus ovatus (L.)	0	0	1	39
*	Symphodus tinca L.	1	129	0	0
*	Xyrichthys novacula (L.)	1	33	2	76
*	Trachinus draco L.	1	59	10	357
*	Uranoscopus scaber L.	1	142	2	287
*	Scomber scombrus L.	0	0	1	23
*	Belone belone L.	0	0	1	51
*	Scorpaena porcus L.	2	153	0	0
*	Scorpaena scrofa L.	15	1483	2	115
*	Trigla lyra (L.)	0	0	1	15
*	Trygla lucerna Brunn.	12	2501	3	233
*	Trigloporus lastoviza (Brunn.)	10	619	0	0
*	Eutrigla gurnardus L.	1	68	6	165
*	Aspitrigla obscura (L.)	0	0	1	10
*	Scophthalmus rhombus L.	4	789	10	1348
*	Psetta maxima (L.)	1	282	0	0
	Bothus podas Delar.	12	233	27	555
	Arnoglossus laterna (Walb.)	1	15	0	0
*	Solea vulgaris Quens.	0	0	3	255
*	Solea variegata (Donovan)	1	23	0	0
*	Pegusa impar Bennett	0	0	10	558
*	Monochirus hispidus Raf.	0	0	2	33

(cont.) TAB. 1

	INVERTEBRATA	STATION A N°	STATION A W (g)	STATION B N°	STATION B W (g)
*	Palinurus elephas (Fabricius)	4	892	0	0
*	Squilla mantis L.	44	1761	9	325
*	Penaeus kerathurus (Forskal)	3	179	7	299
	Pagurus prideauxi (Fabricius)	+	0	+	0
	Medorippe lanata L.	+	0	+	0
*	Calappa granulata (L.)	+	0	8	1136
	Liocarcinus depurator L.	+	0	+	0
	Parthenope macrocheles (Herb.)	+	0	+	0
	Maja verrucosa H. M. Edwards	+	0	0	0
	Inachus sp.	0	0	+	0
	Macropodia longirostris (Fab.)	+	0	+	0
	Naticarius millepunctatus (Chem.)	+	0	+	0
	Neverita josephinia Risso	+	0	0	0
	Cassidaria echinophora L.	+	0	+	0
	Bolinus brandaris (L.)	+	0	+	0
	Phyllonotus trunculus (L.)	+	0	+	0
	Nassarius mutabilis (L.)	+	0	+	0
	Pododesmus patelliformis (L.)	+	0	+	0
	Acanthocardia tuberculata (L.)	+	0	+	0
*	Sepia officinalis (L.)	33	8586	29	5652
*	Loligo vulgaris (Lam.)	1	350	0	0
*	Scaeurgus unicirrhus (D'Orbigny)	1	196	0	0
*	Octopus vulgaris Lam.	0	0	4	3106
	Astropecten bispinosus (Otto)	+	0	+	0
	Holoturia tubulosa Forsch.	+	0	+	0

* = commercial species

MEAN MONTHLY CATCHES

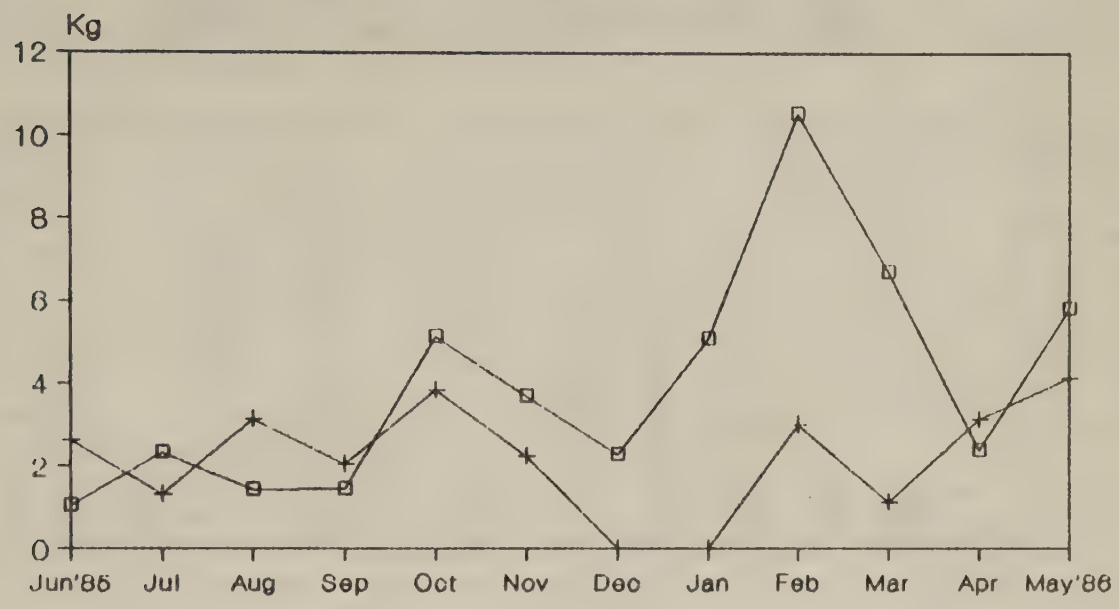


Fig. 3

TAB. 2

	TOTAL AREA	STATION A	STATION B
SURFACE:	1000 HA	200 HA	800 HA
No. SAMPLES:	41	19	22

GROUPS	No. Sp.	CATCHES (KG)	No. Sp.	CATCHES (KG)	No. Sp.	CATCHES (KG)
PISCES	48 65.7%	52	39	35.92	33	16.08
CRUSTACEA	11 15.1%	4.56	9	2.83	9	1.78
CEPHALOPODA	12 16.4%	17.89	12	9.13	9	8.75
ECHINODERMATA	2 2.8 %	-	2	-	2	-
TOTAL:	73	74.45	62 82%	47.88 64.3%	53 72%	26.62 35.7%
MEAN CATCH:		1.8 Kg		2.5 Kg		1.2 Kg

STAT. A
MEAN MONTHLY CATCHES

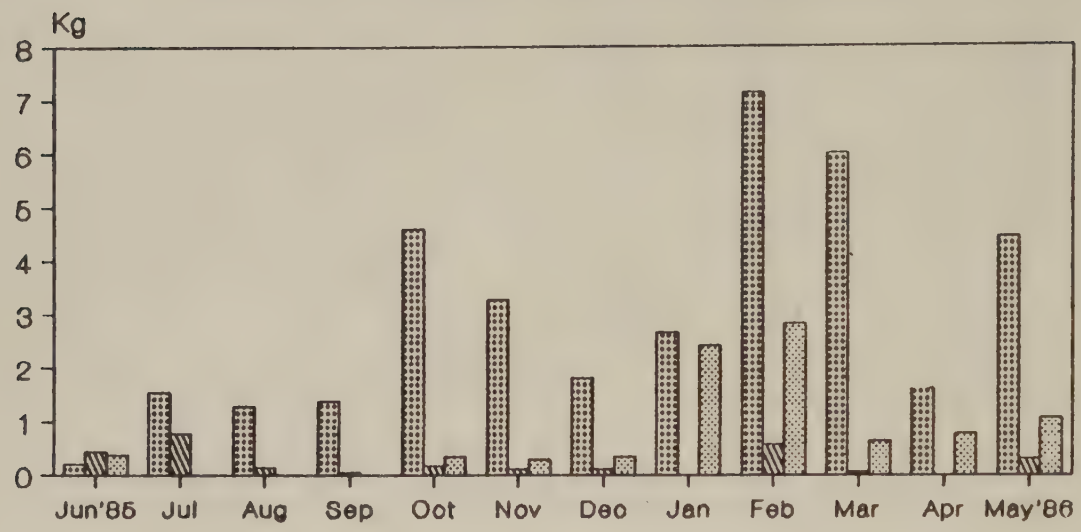


Fig. 4

FISH CRUSTACEA CEPHALOPODS

STAT. B
MEAN MONTHLY CATCHES

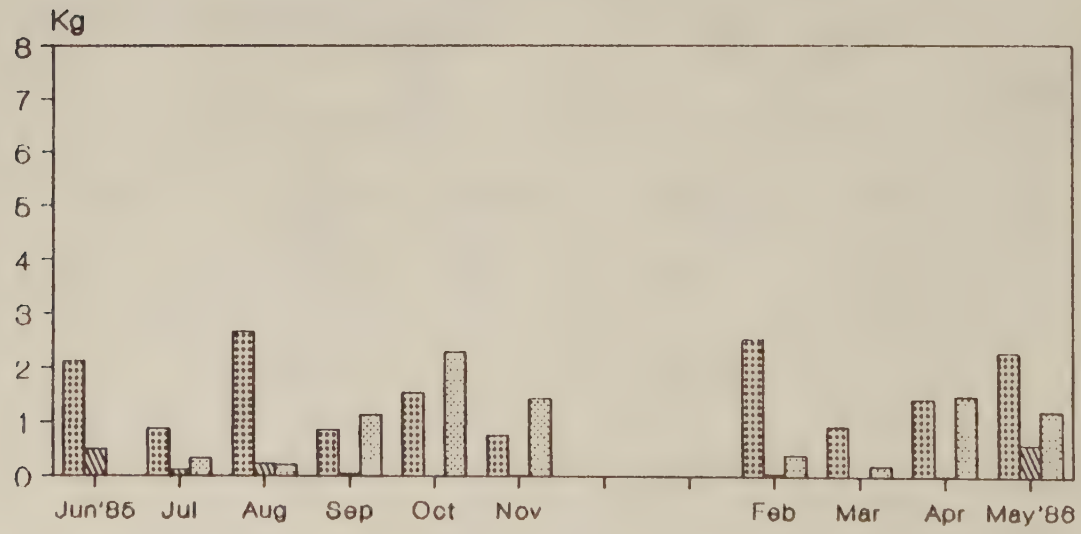


Fig. 5

FISH CRUSTACEA CEPHALOPODS

benthic fauna in the unprotected fishing grounds of **station B.**

The shelter provided by the gentle rocky slope stretching parallel to the shoreline should be added to the favourable factors. A noteworthy recruitment of benthic species takes place from the **Posidonietum** on the slope.

More information can be provided by critical examination of the fish populations on both grounds, in particular of those species restricted to a single station. Fishes related to solid hard substrata are significantly exclusive to **station A** (Table 3). However plaice and minor Pleuronectiformes are instead more represented at **station B.** Some inhabitants of **station A** may be thought of as new immigrants because of their habits of living in the hollows of hard rocks. These may be included among the "resident" taxa. Noteworthy species are **D. sargus** and **P. puntazzo, S. porcus, Spondyliosoma cantharus** and the spiny lobster **Palinurus elephas.**

From examination of the gut contents of the breams (Table 4) a feeding relationship with the boulders can be made evident, although a strict dependence on the reefcommunities should be ruled out. Hydroidea and encrusting Bryozoa are in fact organisms already censused on the concrete substrata and absent from the soft bottoms prevailing at **station B.** Peracarid crustacea are the most frequent prey; the majority of them are represented by opportunistic taxa showing a wide habitat distribution. The genus **Hyale** includes species strictly related to hard substrata and typical of harbour biofouling.

As a conclusion, the higher yields obtained in the restocking area are evidence of a positive influence exerted by the solid substrata. It is however impossible to select one of such factors as the most powerful. Attraction to solid surfaces, increase in the "roughness" of the bottom, provision of food and shelter seem to act simultaneously on nectobenthic fauna.

Attraction is very likely the most active factor of species recruitment during the early phases of colonization. The development of benthic communities and the increase in substratum roughness seem to encourage fish to keep within the range of the outcroppings, possibly attracting other fish up to the "carrying capacity" specific for each reef and very likely dependent on its size. Fishing improvement would therefore result from both aggregation of individuals around the "reference mark" and from the actual increase in population consequent to the greater availability of shelter and food. The effectiveness of a reef in our latitudes should therefore be related to the interplay of many factors, the intensity of which would vary with the local hydrological conditions. Our preliminary fishing survey is just an approach to some questions raised by the use artificial habitats on the sea bottom: much more research will be needed for a better understanding of the whole matter.

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WEIGHT PERCENT COMPOSITION OF CATCHES

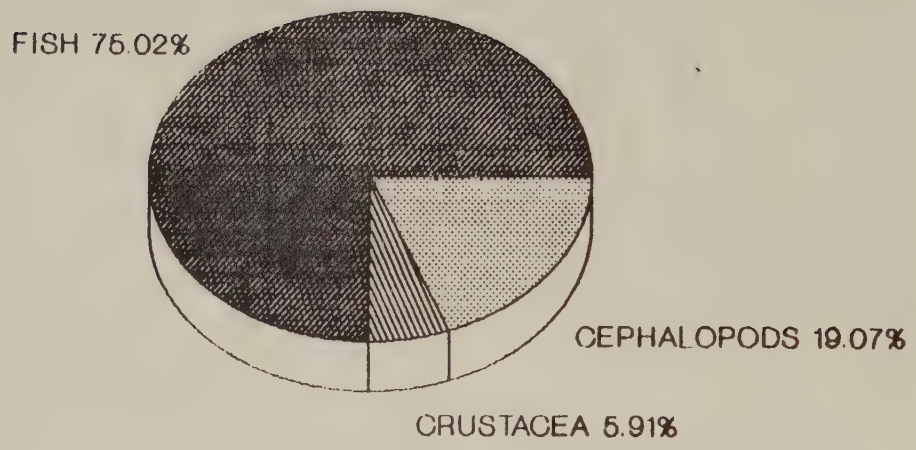

Fig. 6 - STAT. A

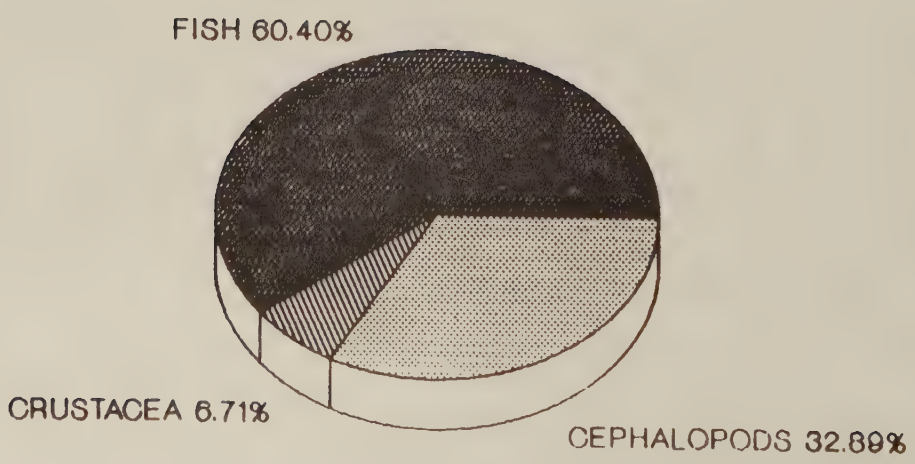

Fig. 7 - STAT. B

TAB. 3 - LIST OF SPECIES EXCLUSIVE TO EACH STATION.

STATION A	STATION B
FISHES	FISHES
Torpedo marmorata Risso	Nettastoma melanurum Raf.
Dicentrarchus labrax (L.)	Trachinotus ovatus (L.)
Serranus scriba (L.)	Scomber scombrus L.
Diplodus sargus (L.)	Belone belone L.
Diplodus puntazzo (Gm.)	Trigla lyra (L.)
Boops salpa (L.)	Aspitrigla obscura (L.)
Spondyliosoma cantharus (L.)	Solea vulgaris Quens.
Spicara maena (L.)	Pegusa impar Bennett
Corvina nigra L.	Monochirus hispidus Raf.
Symphodus tinca L.	
Scorpaena porcus L.	
Trigloporus lastoviza (Brunn.)	
Psetta maxima (L.)	
Arnoglossus laterna (Walb.)	
Solea variegata (Donovan)	
INVERTEBRATA	INVERTEBRATA
Palinurus elephas (Fabricius)	Octopus vulgaris Lam.
Loligo vulgaris (Lam.)	
Scaeurgus unicirrhus (D'Orbigny)	

TAB. 4 - TAXONOMIC GROUPS OF PREY IN GUT CONTENTS OF DIPLODUS ANNULARIS

TOTAL STOMACHS: No. 54
FULL STOMACHS: No. 45 CV = 16.6
EMPTY STOMACHS: No. 9

GROUPS	F	N	P	MFI	Q
ALGAE	42.2	---	---	---	---
HYDROIDA	31.1	6.50	0.14	1.62	0.9
GASTROPODA	11.1	4.69	1.85	5.04	8.6
NUDIBRANCHIA	2.2	0.93	< 0.01	< 0.01	< 0.01
BIVALVIA	17.7	11.73	6.56	9.81	76.9
POLYCHAETA	31.1	6.50	11.67	14.81	75.8
CRUSTACEA	13.3	2.81	< 0.01	< 0.01	< 0.01
OSTRACODA	11.1	2.34	< 0.01	< 0.01	< 0.01
COPEPODA	2.2	0.40	< 0.01	< 0.01	< 0.01
MYSIDACEA	2.2	0.46	< 0.01	< 0.01	< 0.01
BRACHYURA	6.7	1.40	< 0.01	< 0.01	< 0.01
ISOPODA	20.0	4.22	16.78	14.25	70.8
AMPHIPODA	55.5	38.49	36.93	41.65	1416.9
BRYOZOA	11.1	2.34	0.43	1.69	1.0
PISCES	4.4	0,93	25.54	8.25	23.7

F = 100 x No. OF STOMACHS CONTAINING ITEM / No. OF FULL STOMACHS EXAMINED;

N = 100 x No. OF INDIVIDUALS OF ITEM I / TOTAL No. OF INDIVIDUALS:

P = 100 x WEIGHT OF ITEM I / TOTAL WEIGHT OF PREY:

MFI = MAIN FOOD ITEM; Q = FEEDING COEFFICIENT;

CV = VACUITY COEFFICIENT;

Diplodus annularis

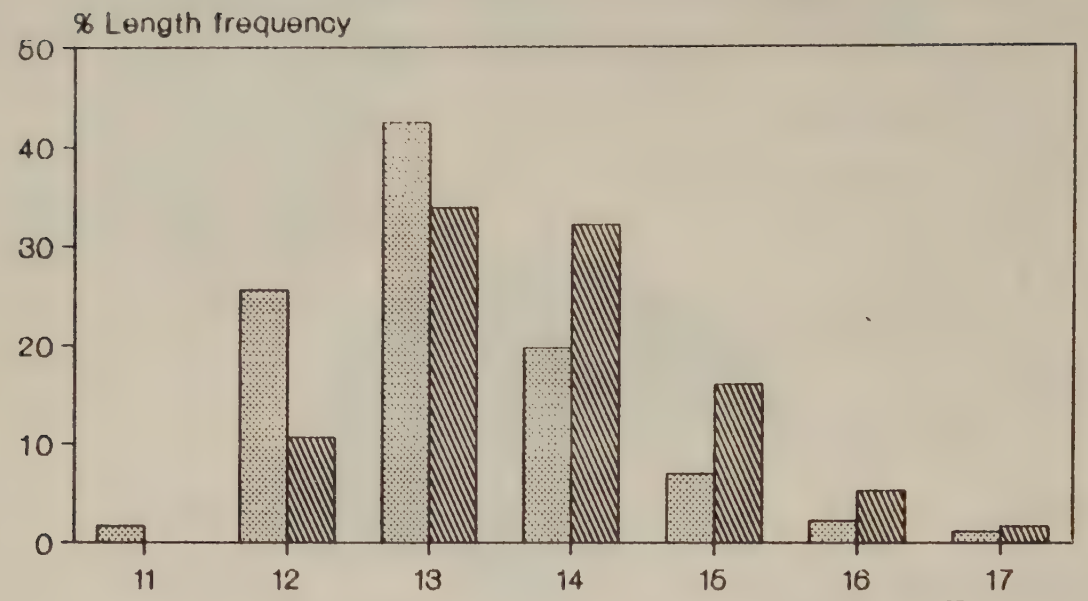

Fig.8 - Distribution of size classes.

STAT. A No = 172 STAT. B No = 56

Pagellus erythrinus

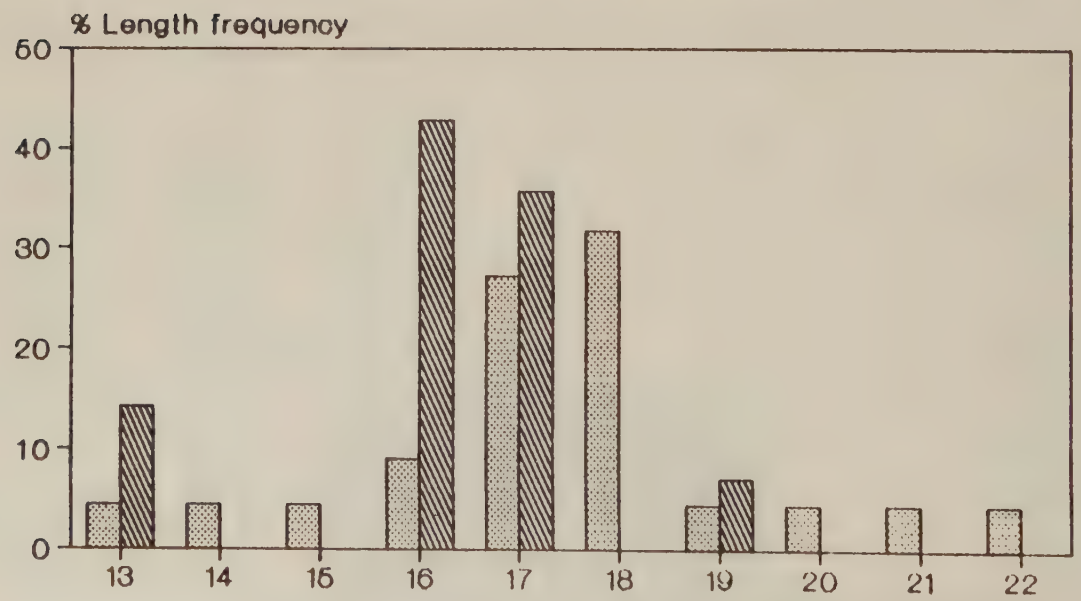

Fig.9 - Distribution of size classes

STAT. A No. = 22 STAT. B No. = 14

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LES POISSONS RECIFAUX

par

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Les études et les essais effectués sur les substrats durs naturels et sur les récifs artificiels montrent que plusieurs espèces de poissons sont attirées, tournent et vivent autour ou à l'intérieur des structures artificielles.

Le phénomène d'attraction est appelé "thygmotropisme", mais il faut de quelque façon expliquer le mécanisme bio-écologique qui en est la base. Il est évident que le thygmotropisme s'explique surtout par la possibilité pour certaines espèces de poissons (poissons brouteurs et carnivores), de trouver les proies qu'elles préfèrent en abondance sur et auprès des substrats durs et de trouver des refuges; tandis que pour d'autres encore il s'agit d'un phénomène mystérieux que Breder et Nigrelli (1983) avaient défini comme "le désir de certains poissons d'être proches de corps solides", autrement dit, le thygmotropisme.

Certainement le comportement peut en grande partie expliquer le phénomène d'attraction, mais ce n'est pas suffisant. Nous voudrions ici appeler l'attention sur la distribution verticale des diverses espèces de poissons qui fréquentent les structures récifales. Cette distribution est clairement liée au comportement alimentaire. Par les techniques visuelles d'observation, on peut remarquer que les espèces des poissons récifaux qui se déplacent d'un récif à l'autre et du sommet d'une structure récifale à sa base, semblent se maintenir de préférence dans différentes couches dans la colonne d'eau et occuper des niches diverses.

On peut les partager en trois groupes:

A - Pélagiques - epirécifales

B - Néctobénthiques - mésorécifales (que l'on peut encore subdiviser en espèces inter-récifales et intrarécifales.

C - Bénthiques - hyporécifales (Cavitaires ou non)

A - Pélagiques - epirécifales

Il s'agit des espèces qui sont attirées par l'extrémité supérieure des structures récifales et en particulier par les corps flottants et ondulants (fish attracting devices, FAD).

Les espèces plus fréquentes sont: Boops boops, Scomber scombrus, Scomber japonicus, celles des genres Spicera et Trachurus, et occasionnellement Liza aurata, L. ramata, L. saliens, Mugil cephalus, Chelon labrosus, Belone belone, Engraulis enchrasicholus, Sardina pilchardus, etc.

B - Néctobénthiques - mésorécifales

Il s'agit d'un groupe d'espèces ayant un rapport vraiment constant avec les substrats durs, qu'ils soient naturels ou artificiels, et qui constituent le noyau le plus important des espèces récifales. Ces espèces se tiennent de

préférence dans les couches d'eau intermédiaires, mais avec de fréquents déplacements vers le fond en général et parfois vers la surface.

On peut distinguer, parmi celles-ci, un premier groupe qui se tient de préférence à l'extérieur des substrats et des modules récifaux et qui se déplace d'une structure à l'autre (espèces interrécifales), comme les sparidés Dentex dentex, Diplodus annularis, D. puntazzo, D. sargos, D. vulgaris, Oblada melanura; le groupe des pageots Pagellus acarne, P. bogaraveo, P. erythrinus; les pagres Pagrus pagrus, Sparus aurata et Spondyliosoma cantharus, et parfois les labridés Labrus bimaculatus et Symphodus tinca. On peut ajouter enfin deux espèces migratrices à présence saisonnière: Seriola dumerili et Balistes carolinensis.

Un deuxième groupe d'espèces mésorécifales, qu'on peut appeler intrarécifales, se tiennent de préférence à l'intérieur des structures , à la recherche d'un refuge (comme les sciaenidés (Sciaena umbra et Umbrina cirrosa) ou dans des cavités d'où elles sortent pour chasser leurs proies (comme Dicentrarchus labrax et Conger conger).

C - Bénthiques - hyporécifales

Il s'agit d'espèces inféodées aux substrats durs, qui vivent et pondent de préférence dans des cavités, comme les gobidés Gobius cobitis, G. niger, G. paganellus; les scorpaenidés Scorpaena porcus, S. hepatus et S. cabrilla. On peut y ajouter deux ou trois espèces de blennidés.

On a enfin, un groupe d'environ 40-50 espèces qui fréquentent habituellement les récifs artificiels et que l'on peut observer directement en plongée et capturer par des engins fixes (trémail, filets maillants, palangres, etc.). Certaines de ces espèces sont-elles saisonnières?

Ce stock de poissons récifaux est très important du point de vue economique, mais il faut l'aménager de façon sérieuse et prudente car il s'agit en général d'espèces à durée de vie moyenne plutôt brève et certaines d'entre elles (sparidés p. ex.) connaissent pendant leur vie des moments délicats comme le changement de sexe.

Reste à savoir s'il s'agit d'espèces simplement attirées par les substrats durs ou d'une nouvelle biomasse qui se forme auprès des récifs. Pour répondre à cette question, d'ailleurs très importante, il faut commencer par:

1. vérifier quelles sont les espèces récifales qui pondent sur des substrats durs;

2. vérifier que les structures récifales assurent une véritable réduction de la mortalité des juvéniles pendant la phase de prérecrutement à la pêche.

Tels sont les problèmes sur lesquels il faut se pencher dans l'immédiat. Ce qui est certain, pour le moment, c'est l'augmentation quantitative et le changement qualitatif des rendements de la pêche.

PRELIMINARY ANALYSIS OF CATCH DATA FROM ARTIFICIAL REEFS IN CENTRAL ADRIATIC

by

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INTRODUCTION

Artificial reef literature includes numerous observations of high fish densities, rapid colonization and high catch rates at artificial reefs as a result of their attraction effect and increased production (Bonsack and Sutherland, 1985).

Increased production is most likely in areas far from natural reefs and in the case of habitat-limited, demersal and territorial species of hard substrates, whereas fish attraction should be more significant in locations with natural reef habitats and for pelagic, mobile, partially reef-dependent and opportunistic reef species.

In fact, in the first case, besides providing additional food and increasing feeding efficiency, suitable artificial substrates can also provide shelter from predators and a greater habitat availability for recruits that would otherwise be lost (Bonsack, 1989).

Moreover, although several authors have suggested that species resident around artificial reefs can affect the fish in the surrounding habitat through predation (Davis *et al.*, 1982; Bonsack and Sutherland, 1985), in some cases it has been demonstrated that artificial substrates in sandy-bottom areas can increase the abundance of reef-dwelling species without any negative effect on the indigenous fish populations (Alevizon and Gorham, 1989).

Similar results have also been obtained for the first concrete artificial reef established along the coast of the central Adriatic (Porto Recanati). Visual observation and set-gear catches (trammel and gill net) demonstrated a drastic increase of benthic and nekto-benthic hard-substrate species (such as *Dicentrarchus labrax*, *Dentex dentex*, *Sparus aurata*, *Conger conger*, Scorpaenidae, etc.) as well as an increase of the original fish population biomass, probably as a consequence of the protective action against illegal trawling and the availability of food and shelter (Bombace, 1977 and 1982).

In order to further confirm these observations, a research programme of experimental catches is being carried out in three coastal areas of the central Adriatic, where concrete multiple-use reefs (Bombace, 1987 and 1989) have recently been deployed.

The aim of this study is to follow the effect of artificial interference on the evolution of fish assemblages and on the catch over the years.

This paper gives the preliminary results from catch data obtained during the first three years of sampling.

MATERIALS AND METHODS

Area description

The western central Adriatic sea is characterized by a flat sandy coast interrupted at only two points by the Gabicce and the Conero promontories. The sandy bottom slopes slightly offshore gradually changing to muddy as the depth increases.

As in the case of the whole Adriatic sea, this area is also highly productive because of the great amount of energy (phyto and zooplankton), particularly in the nearshore waters, but poor in species because of the monotonous habitat.

In fact the indigenous fish assemblage of the coastal area is mainly constituted by pelagic fish such as *Sardina pilchardus*, *Engraulis encrasicholus*, *Sprattus sprattus*, *Mugil cephalus*, *Liza* spp., and by benthic and nekto-benthic species such as *Mullus barbatus*, *Solea* spp., *Gobius* spp., *Trigla lucerna*, *Lithognathus mormyrus* (Froglia, 1984). Moreover, most of these move from nearshore to open sea and vice-versa in relation to seasonal water-temperature changes and spawning.

Study site and reef deployment

All three sites (200 ha) are located on sandy-muddy bottoms at a depth of 10-11 m (Figure 1), inside the 3-mile costal area where trawling is forbidden by law. The reefs are placed at the centre of each area and consist of one or more oases (0.6 ha) of 29 pyramids, each made of 5 concrete blocks, deployed in a rectangular arrangement. The top blocks of

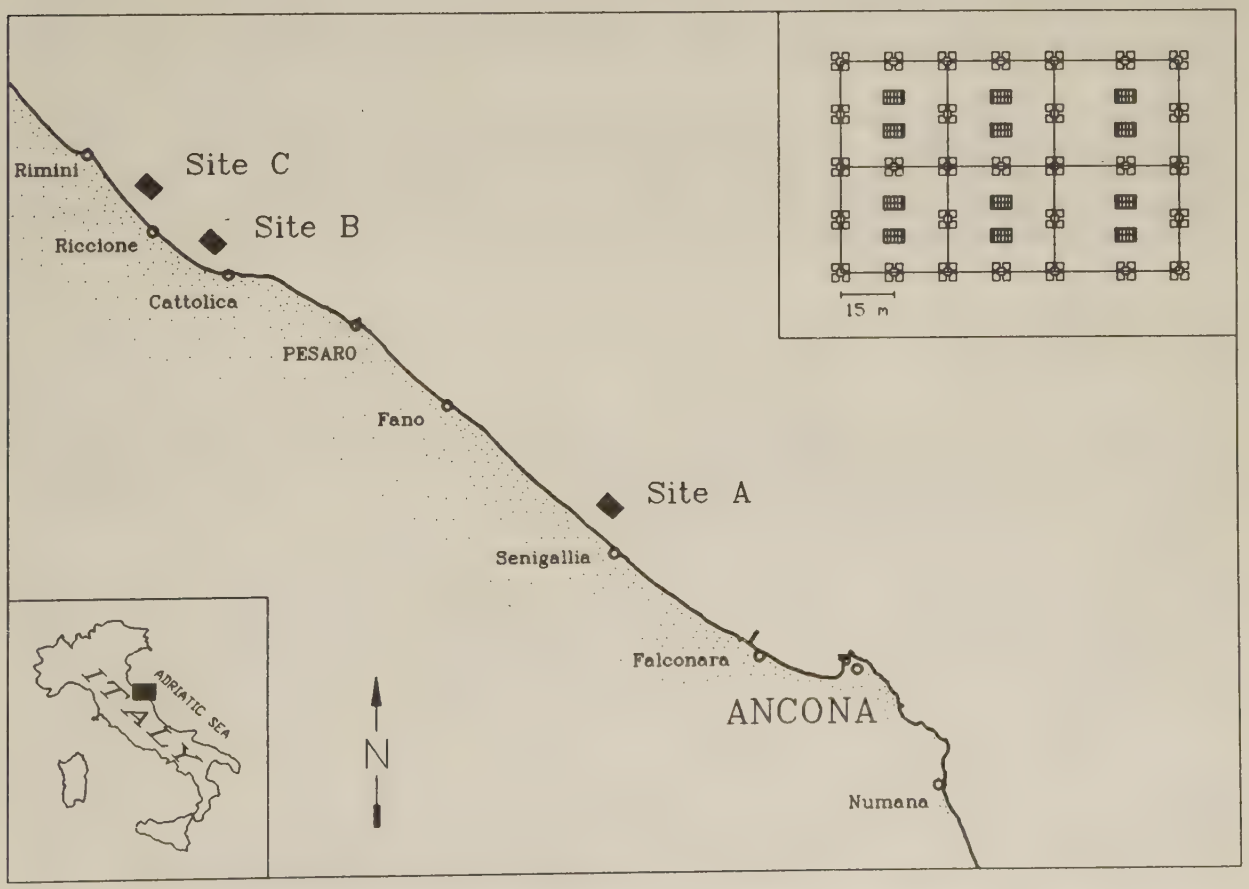


Figure 1 - Location of the three study sites along the central Adriatic coast, and the layout of the artificial reef oasis.

the pyramids are connected to each other by steel wires for mussel and oyster culture and are surrounded by four concrete cylinders on the base blocks. Twelve concrete cages (4x6x5 m) for shellfish culture were immerged among the pyramids. The oases are protected against illegal fishing by anti-trawling bodies (Bombace, 1987 and 1989).

Site A: situated about 15 miles NW of Ancona and 1.2 miles offshore. This is an experimental one-oasis model completed in October 1987 and constructed on behalf of the I.R.PE.M. (Istituto di Ricerche sulla Pesca Marittima) - C.N.R. (Consiglio Nazionale delle Ricerche) in Ancona.

Site B: situated about 1.6 miles NNW of Cattolica and 1.5 miles offshore. This reef was established on behalf of the Associazione Produttori Pesca of Cattolica and was completed in June 1988. It consists of four oases.

Site C: situated about 4 miles NW of site B and 1.5 miles offshore. The reef was established on behalf of the Cooperativa Pescatori "G. Astrea" of Rimini and was completed in May 1988. It consists of three oases.

Data collection

Since 1987, catch samples have been obtained at each site, on a fortnightly or monthly basis, with a standard trammel net (length 500 m; height 2 m; 70 mm inner mesh size and 340 mm outer mesh size) and especially leased commercial fishing vessels.

The net was lowered into the water at sunset and pulled in at dawn, for an average of 12 hours at sea.

Site A was sampled continuously from April 1987 to November 1989, for a total of 36 catches; site B was monitored from May 1987 to May 1988 and from February to November 1989, for a total of 32 catches, and 24 catches were carried out from June 1987 to May 1988 and from March to November 1989 at site C. The fishing survey is still being continued at each site.

All the fish in the catches was measured (total length), weighed and sexed, with the exception of the sardines (*S. pilchardus*) and anchovies (*E. encrasicholus*), which were only counted and weighed. The same was done for the cephalopods (mantle length) and crustaceans (carapace length) of economic interest, except for the *Squilla mantis*, the males and females of which were counted and weighed separately.

Data analysis

The catch data were processed using specific computer programmes. All fish species caught were coded using the Clofnam code (Whitehead *et al.*, 1984). For the molluscs and the crustaceans a similar code to Clofnam was created on the basis of the "FAO species identification sheets for fishery purposes" (Fischer *et al.*, 1987).

Pelagic, nekto-benthic and benthic fish, as well as molluscs and crustaceans, were treated separately, in order to show better the effect of reef deployment on each group.

Because of some differences of the net time at sea (longer in winter than in summer) and because trammel nets were sometimes damaged, all catch data were standardized to number and weight per 12 hours and per 500 m of trammel net. The data obtained in this way have been plotted in Figures 2, 3 and 5.

Two similar sampling periods were chosen to compare better the catch data obtained before and after reef deployment among the three sites: May 1987-April 1988 and January-November 1989. Since the reef at site A was completed in October 1987, the data from November 1987 to April 1988 were obtained from catches carried out in a similar area (same depth, distance from the coast and bottom type) about 2.5 miles far from the reef.

Average number and weight per single catch for all the species caught in these two periods are reported in Table 1.

Table 1 - List of the species caught at the three sites before and after reef deployment. The average number of specimens and the average biomass per standardized catch (500 m of trammel net and 12 hours at sea) are also reported for each species (P = pelagic; NB = nekto-benthic; B = benthic).

		Site A				Site B				Site C			
N. catch operations		Before 14		After 12		Before 17		After 13		Before 11		After 12	
		n.	W(g)	n.	W(g)	n.	W(g)	n.	W(g)	n.	W(g)	n.	W(g)
PISCES													
BOTHIDAE													
Amoglossus laterna	B	0.1	3			0.4	9	0.4	10	0.6	11	0.2	4
CARANGIDAE													
Trachurus mediterraneus	P	0.2	40	0.1	10	0.6	49	0.4	62	8.3	690	3.2	447
Trachurus trachurus	P			0.1	1	0.1	3			0.2	5		
CARCHARHINIDAE													
Carcharhinus plumbeus	NB											0.1	170
CENTRACANTHIDAE													
Spicara flexuosa	P	0.6	45	2.0	154			0.1	5	0.1	4		
CLUPEIDAE													
Alosa fallax	P	0.6	192	0.1	45	1.0	271	0.6	158	0.4	103	1.5	625
Sardina pilchardus	P	61.2	2393	16.4	596	85.9	3703	47.7	1873	133.6	5986	49.2	2121
ENGRAULIDAE													
Engraulis encrasicholus	P	0.4	8	3.0	30	6.2	85	6.8	75	37.0	488	51.7	638
GADIDAE													
Gaidropsarus mediterraneus	B			0.4	83								
Merlangius merlangus	NB			0.2	12							0.8	136
GOBIIDAE													
Gobius niger	B	0.5	14	0.1	2	0.8	18			0.8	16	0.2	6
MERLUCCIIDAE													
Merluccius merluccius	NB	0.1	5							0.2	7	0.1	4
MORONIDAE													
Dicentrarchus labrax	NB	0.1	25										
MUGILIDAE													
Chelon labrosus	P					0.1	7					0.1	44
Liza aurata	P	0.1	6										
Liza ramada	P	0.6	194	13.6	7371	0.2	132	0.1	53			0.1	31
Liza saliens	P	0.1	19	0.4	112	0.5	194	0.1	41				
Mugil cephalus	P	0.1	30	1.6	544			0.3	145	0.1	23	0.2	121
MULLIDAE													
Mullus barbatus	B	0.5	12	0.1	2					0.6	12	0.2	8
MYLIOBATIDAE													
Pteromylaeus bovinus	NB									0.1	104		
PLEURONECTIDAE													
Platichthys flesus	B					0.2	19			0.3	78		
SCIAENIDAE													
Sciaena umbra	NB			2.2	545			0.9	226			1.4	307
Umbrina cirrosa	NB	0.1	11	0.2	70	0.1	15	0.5	188	0.1	28	2.6	819
SCOMBRIDAE													
Scomber japonicus	P									0.1	31	0.1	38
Scomber scombrus	P	0.7	58			0.1	8			0.3	27	0.4	122

Table 1 - Cont.

		Site A				Site B				Site C			
		n.	W(g)	n.	W(g)	n.	W(g)	n.	W(g)	n.	W(g)	n.	W(g)
SCOPHTHALMIDAE													
Psetta maxima	B	0.1	17			0.1	22						
Scophthalmus rhombus	B					0.1	15	0.1	25			0.1	14
SCORPAENIDAE													
Scorpaena porcus	B			1.1	136					0.1	14	0.1	9
SOLEIDAE													
Buglossidium luteum	B	1.2	12	2.7	35	0.9	11	1.9	23	2.4	24	2.0	26
Solea impar	B	1.5	79	1.5	88	1.8	82	2.6	121	6.0	251	0.8	33
Solea vulgaris	B	5.3	521	9.5	864	2.1	122	4.9	372	5.6	284	3.7	196
SPARIDAE													
Boops boops	P	0.4	50	0.1	4	0.2	24	0.4	28	0.7	54	0.9	85
Diplodus annularis	NB	0.2	16	0.3	26	0.1	7	0.2	11	0.2	14	3.5	355
Lithognathus mormyrus	NB	0.3	59	0.6	137	0.3	45	0.2	45	0.4	77	0.8	124
TRACHINIDAE													
Echiichthys vipera	B					0.4	6	0.1	1				
TRIAKIDAE													
Galeorhinus galeus	P	0.1	33										
Mustelus mustelus	NB	0.6	98									0.1	6
TRIGLIDAE													
Trigla lucerna	B	3.5	287	1.6	178	1.0	138	3.4	306	1.3	102	2.8	384
CRUSTACEA													
MAJIDAE													
Maja crispata				0.2	14								
Maja squinado		0.1	36							0.1	34		
PENAEIDAE													
Penaeus kerathurus								0.2	10			0.2	7
PORTUNIDAE													
Carcinus aestuarii		0.1	3										
SQUILLIDAE													
Squilla mantis		33.9	1759	30.3	1645	7.6	400	20.7	1082	25.3	1116	18.8	930
XANTHIDAE													
Eriphia verrucosa				0.1	9								
MOLLUSCA													
LOLIGINIDAE													
Alloteuthis media								0.1	1				
Loligo vulgaris		0.1	7	0.1	48	0.1	26						
MURICIDAE													
Rapana venosa		0.4	56	0.4	66								
OCTOPODIDAE													
Eledone moschata				0.1	19			0.1	56				
SEPIIDAE													
Sepia officinalis		3.5	1085	3.4	1154	2.8	862	2.5	982	4.8	1532	3.4	742
SEPIOLIDAE													
Sepiola rondeleti				0.2	21					0.1	1		

Table 2 - Average number of specimens and average biomass of pelagic, nekto-benthic and benthic fish, crustaceans and molluscs in catches before and after reef deployment.

	Site A				Site B				Site C			
N. catch operations	Before 14		After 12		Before 17		After 13		Before 11		After 12	
	n.	W(g)	n.	W(g)	n.	W(g)	n.	W(g)	n.	W(g)	n.	W(g)
PELAGIC FISH	65.0	3069	37.3	8868	94.8	4475	56.6	2441	180.7	7410	107.2	4273
NEKTO-BENTHIC FISH	1.4	214	3.4	790	0.5	67	1.8	470	0.9	230	9.3	1921
BENTHIC FISH	12.5	945	17.0	1388	7.7	442	13.4	859	19.3	842	9.8	680
CRUSTACEANS	34.0	1798	30.6	1668	7.6	400	20.9	1092	25.4	1150	19.0	936
MOLLUSCS	3.9	1148	4.2	1307	2.8	888	2.7	1038	4.9	1533	3.4	742
TOTAL	16.8	7174	92.5	14021	113.4	6272	95.4	5900	231.2	11165	148.7	8552

RESULTS

Pelagic fish

These are generally transient, gregarious species, which may be temporarily attracted by the upper ends of artificial substrates. They have always constituted the majority of trammel net catches, both in terms of number and weight, in all the sites before (72% in number and 60% in weight) and after reef deployment (57% in number and 52% in weight). The principal species were *S. pilchardus* and *E. encrasicholus* and the highest catches were recorded at each site in the autumn of each year (Figure 2).

During the survey period, an increase of *E. encrasicholus* was recorded at each site after reef construction, whereas *S. pilchardus* decreased drastically.

No significant differences were noted for the other pelagic species, except for an evident increase of *Spicara flexuosa* and Mugilidae at site A after reef deployment (Table 1).

Nekto-benthic fish

There was a low proportion of this group in catches before reef deployment, particularly at sites B and C. After substrate immersion, a general increase was recorded at all sites, more significant at site C (10.3 times in number and 8.4 times in weight) than at site A and site B (2.4 and 3.6 times in number; 3.7 and 7.0 times in weight, respectively) (Table 2). Figure 3 clearly shows the gradual increase over the years at site A. Unfortunately, data immediately after deployment of the reef are not available for sites B and C.

Most of these nekto-benthic fishes, which are of high commercial value, like the Sciaenidae and the Sparidae, are known to prefer hard substrates.

Some of them were previously present at the sites and increased substantially in number (i.e., *Diplodus annularis* and *Umbrina cirrosa*) after reef immersion, while others, such as *Sciaena umbra*, which is a typical reef-dwelling fish, appeared subsequently (Table 1).

Seasonal fluctuations in the nekto-benthic fish catch were recorded at all three sites. In fact, they appeared in catches from early-spring to late-autumn, with the highest values

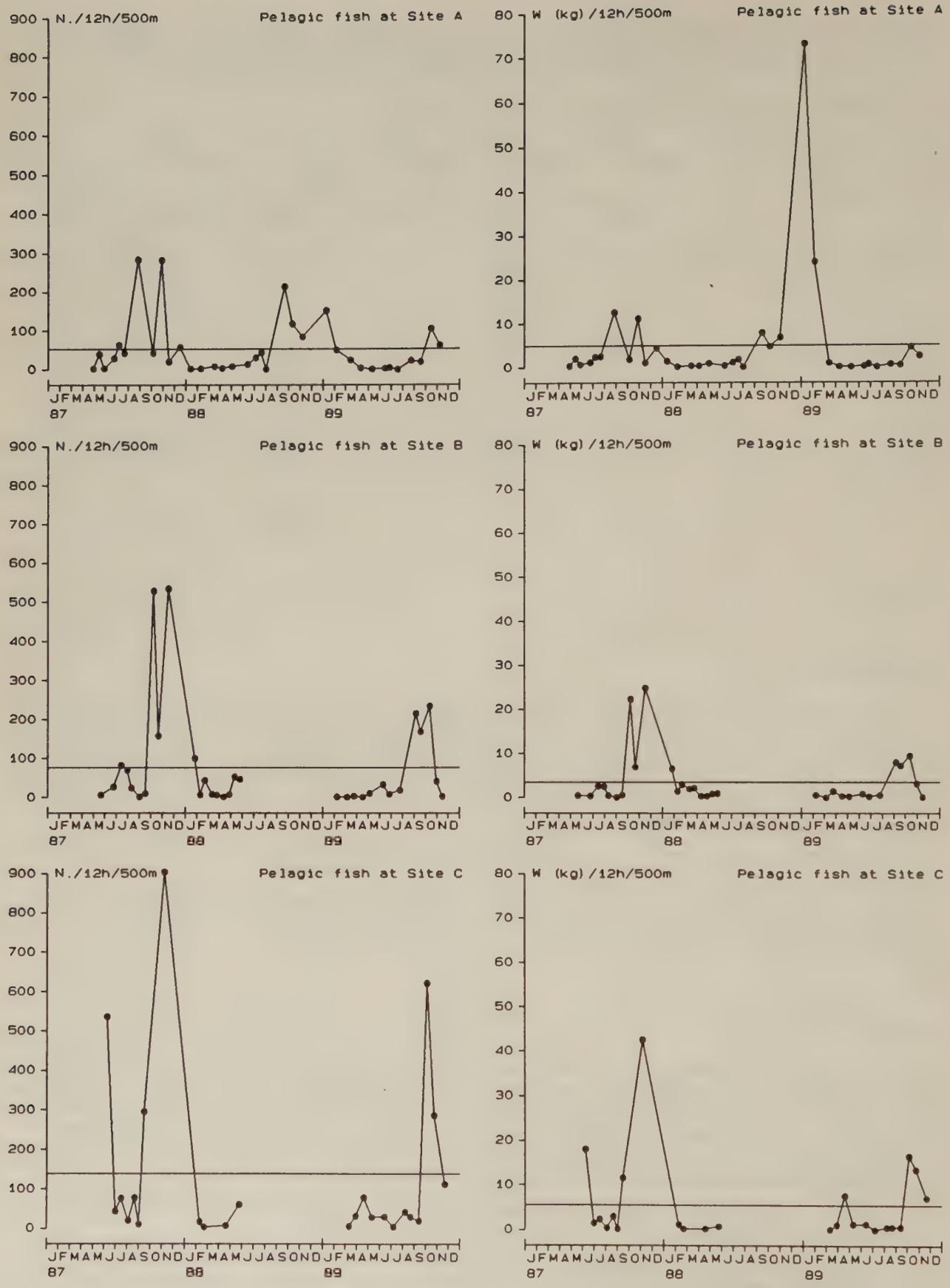
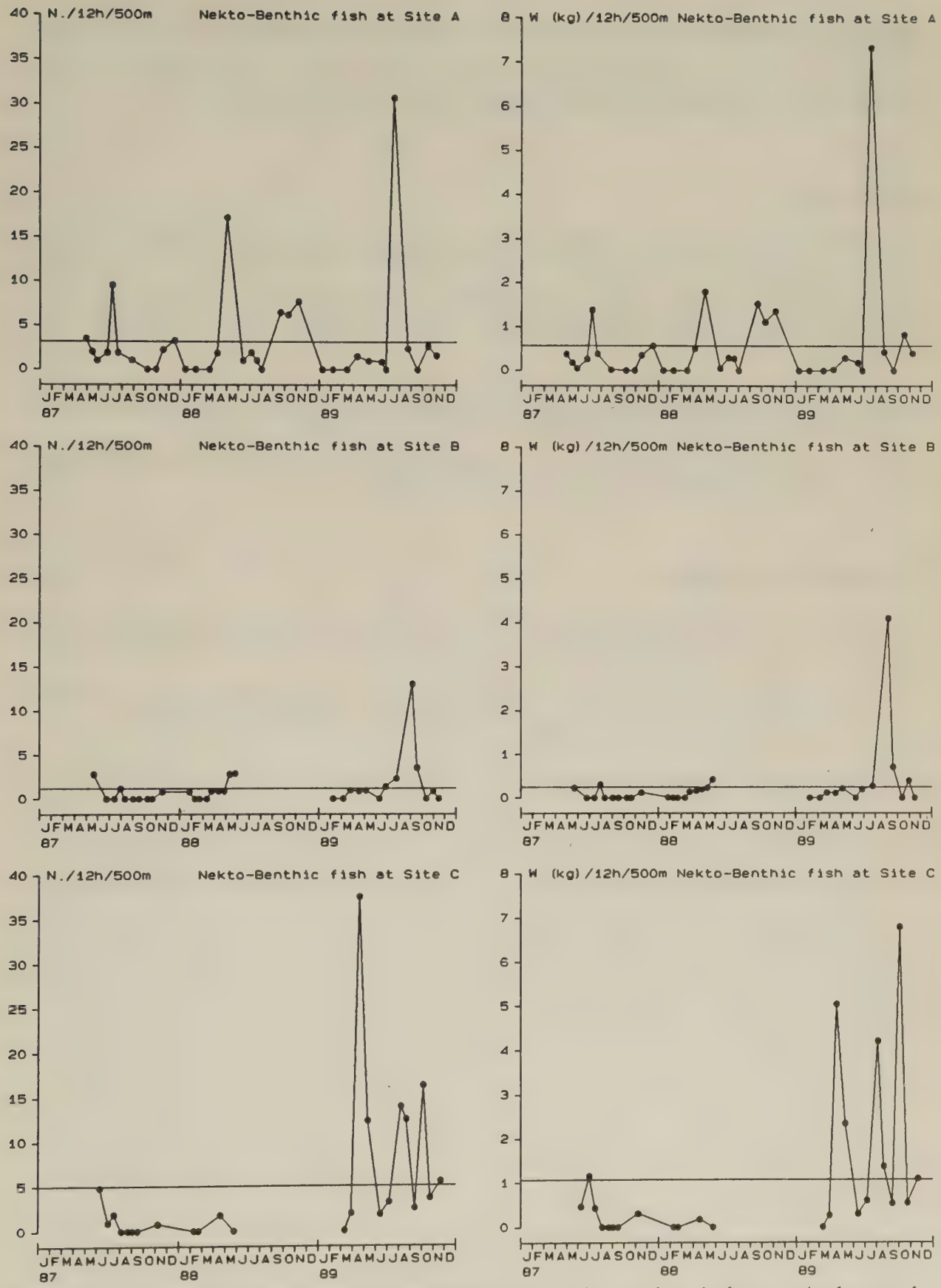


Figure 2 - Number and biomass of pelagic fish in catches before and after reef deployment. The horizontal lines represent the average values estimated for the whole survey period.


N./12h/500m Nekto-Benthic fish at Site A
W (kg)/12h/500m Nekto-Benthic fish at Site A
N./12h/500m Nekto-Benthic fish at Site B
W (kg)/12h/500m Nekto-Benthic fish at Site B
N./12h/500m Nekto-Benthic fish at Site C
W (kg)/12h/500m Nekto-Benthic fish at Site C
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87
88
89

Figure 3 - Number and biomass of nekto-benthic fish in catches before and after reef deployment. The horizontal lines represent the average values estimated for the whole survey period.

recorded in late-spring and summer, and practically disappeared during the winter months (Figure 3).

Figure 4 shows a significant increase in richness for these species at sites B and C, whereas there are no significant differences at site A after reef immersion.

Benthic fish

Benthic fish were present in catches all the year around, reaching the highest values in summer and autumn, and the lowest in the winter months, before and after reef construction.

They included sandy-muddy bottom species, which make seasonal migrations from/to the nearshore for spawning and early growth (i.e., *Solea vulgaris* and *T. lucerna*), as well as resident fish which preferably live and/or spawn in shelters, such as Gobiidae and Scorpenidae.

Flat-fish represented the highest proportion of benthic fish at each site and at all times during the survey period (Table 1). They were mainly Soleidae, which increased considerably in number in catches after reef deployment at site A and B, but not at site C.

For the moment, the only species appearing after reef immersion were *Scorpaena porcus* and *Gaidropsarus mediterraneus* at site A (Table 1).

Crustaceans and molluscs

The most abundant crustacean of economic interest in our catches was *S. mantis*, which lives in a sandy-muddy bottom and does not seem to be a reef-dependent species. Moreover, its catch is strongly affected by sea conditions.

The only reef-dwelling species were represented by one specimen of *Eriphia verrucosa* and two specimens of *Maja crispata* caught at site A after reef deployment (Table 1).

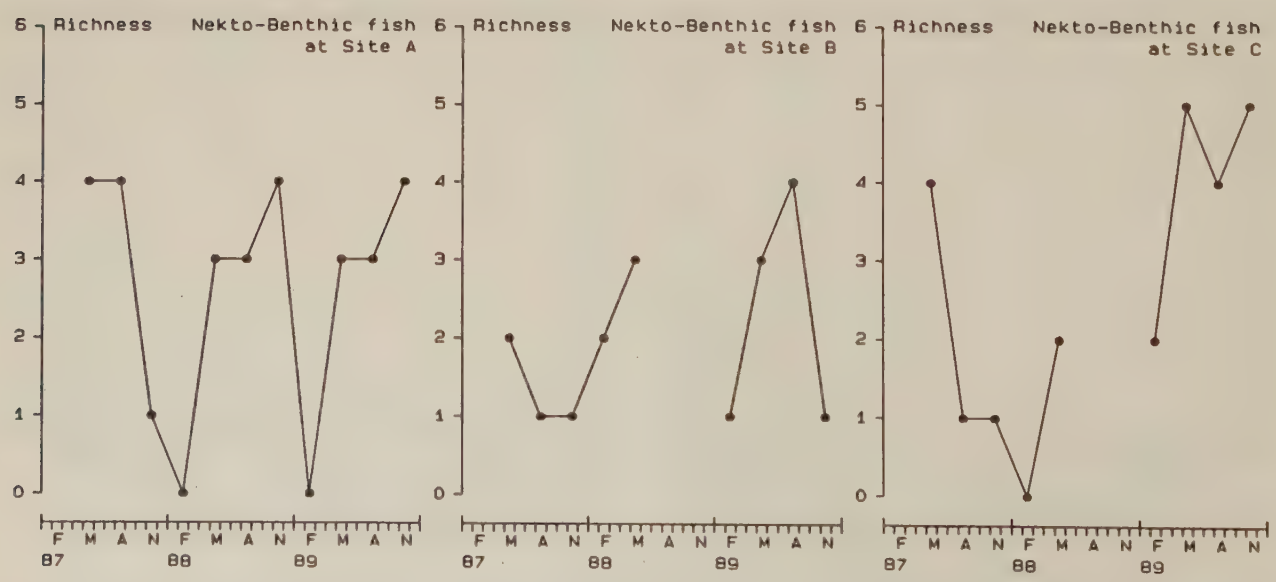

Figure 4 - Richness (total number of different species caught in each quarter) of nekto-benthic fish before and after reef deployment.

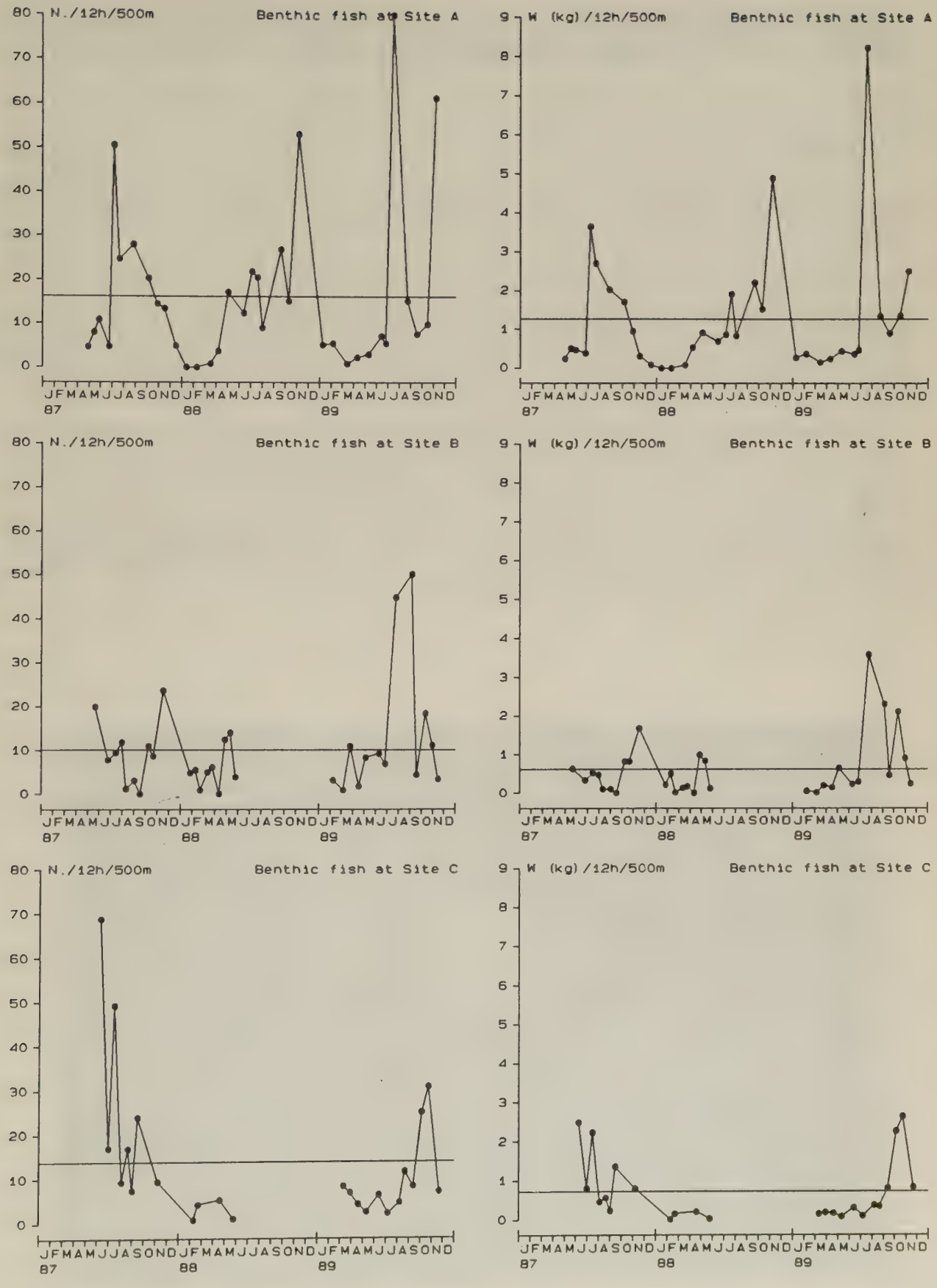

Figure 5 - Number and biomass of benthic fish in catches before and after reef deployment. The horizontal lines represent the average values estimated for the whole survey period.

Molluscs were mainly cephalopods. The most abundant of these was the *Sepia officinalis*, a sandy-muddy bottom species, which concentrates nearshore in spring for spawning. There were no significant differences in its catch after reef immersion (Table 1).

DISCUSSION

According to Bombace (1982), these preliminary catch data showed that selected species, which were absent or rare in the original habitat, appeared or increased at reef deployment sites, just one year after the immersion of artificial substrates.

Moreover, we have reason to believe that a higher number of reef-dwelling species and of specimens for each species is present at reefs relative to what is reported in catch data.

In fact, visual observations carried out after reef deployment at site A by divers with video and photo cameras revealed the presence of many nekto-benthic hard-substrate species, such as *D. labrax*, *Serranus scriba*, *Diplodus sargus and Diplodus vulgaris* (Figure 6), as well as pelagic reef-attracted fish, such as *Seriola dumerilii* and *Balistes carolinensis*, and juvenile forms which did not appear in trammel net catches.

The fact that these were not caught is probably a consequence of the species (and size) selectivity of the fishing gear used, of the impossibility of setting the net just inside the reef because of the presence of shellfish farming structures (concrete cages and steel wires between the tops of the reef pyramids) and of different fish behaviour.

The disappearance from the reefs of most species during the winter months, showed by catch data, was also confirmed by visual observations. It is probably due to a migration offshore towards deeper bottoms, as a consequence of the low winter temperature recorded in the shallow waters of the reef sites (the annual range is 5-25°C).

Figure 6 - One specimen of *Diplodus vulgaris* near a base block of a pyramid at site A

Regarding the fish assemblage of the original bottom, the data obtained seem to demonstrate that it is not negatively affected by reef deployment. In fact, no significant changes in resident fish biomass and in species number have been shown.

The total average catch data obtained after reef deployment show a biomass increase at site A, a little decrease at site B and a more important decrease at site C. However, these values are only relatively significant in demonstrating the real effect of the reef on fish population, because they are strongly affected by occasional high catches of some pelagic fish and *S. mantis*.

Moreover these result refer to the early stage of the reef life and they might be affected by some difference in the reef deployments (reefs A was completed 7-8 months before reefs B and C).

There is still much discussion, however, as to whether artificial substrates actually increase the new fish biomass or whether they simply attract fish from the surrounding areas, without increasing the total biomass. Both attraction and production are likely to contribute to the reef effects but, while attraction can be explained by fish behavioural mechanisms, the increase of biomass has not yet been demonstrated scientifically, with a single exception (Polovina and Sakai, 1989).

Comparison of catch data obtained before and after reef deployment, and visual observation, can certainly be useful for this purpose, but they have to be combined with other experimental scientific approaches.

On the other hand, no doubt exists about the role of artificial reefs in increasing sessile fauna biomass, especially in eutrophic waters, where their deployment results in the introduction of new surfaces for settling larvae which, in the absence of suitable substrates, would be lost.

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The authors would like to thank Dr. M. Maffei, A. Piersimoni, Dr. M.C. Totti and the entire staff of the Cooperativa Ecomar for catch data collection and laboratory work. Thanks also to C. Giorgetti, G. Giuliani, V. Palumbo and G. Vidulich for the field assistance. Finally, especial thanks to G. Gaetani who also helped in underwater operations and observations.

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SHELLFISH CULTURE ASSOCIATED WITH ARTIFICIAL REEFS

by

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INTRODUCTION

In Italy, shellfish culture consists mainly of mussel farming (*Mytilus galloprovincialis* Lamarck), using floats or poles, carried out only in those areas which are sufficiently protected from wave action, such as the Gulf of Trieste (northern Adriatic), the Gulf of Manfredonia (southern Adriatic), the Gulf of Naples and the Bay of La Spezia (Tyrrhenian Sea) and the Gulf of Taranto (Ionian Sea).

F.A.O. statistics (F.A.O., 1989 a and b) summarized in Table 1, and data collected by the Laboratorio Centrale di Idrobiologia (Della Seta, 1988) report a total production of 135,346 tons (77% of the total Mediterranean production) of molluscs (cephalopods excluded) in Italy for 1987; of these, 85,400 tons are mussels from natural banks (42.7%) and parks (57.3%). Oyster production is so low that it is not mentioned in the official statistics.

These quantities do not satisfy national consumption. In fact, in 1987, about 17,233 tons of mussels (*Mitilus edulis* Linnaeus) and 2,308 tons of oysters (*Ostrea edulis* Linnaeus and *Crassostrea gigas* Thunberg) were imported.

It is therefore necessary to increase Italian shellfish culture by extending it to other areas.

Studies carried out since 1974 by the I.R.Pe.M. of Ancona on artificial reefs have demonstrated the possibility of utilizing such submerged structures not only for fish attraction and for protection of the coastal area against illegal trawling, but also as submerged shellfish farms in open-sea areas with eutrophic water, such as the Adriatic Sea, where traditional culture methods are impracticable because of the absence of protected bays (Ardizzone and Bombace, 1983; Bombace 1987).

The data reported in this paper were obtained from a number of mussel and oyster culture cycles carried out using two experimental reefs situated along the coast of the central Adriatic Sea (Figure 1).

The first one is a small artificial reef immersed in 1983 in the bay of Portonovo (Conero promontory), about 5 miles south of Ancona and characterized by sandy bottom and rocky shores where mussels and oysters grow abundantly on natural banks.

The reef, situated about 0.5 miles offshore at a depth of 10 m, consists of four pyramids, placed at the corners of a square area (each side about 20-25 m) and each formed by 5 concrete cubic blocks (2x2x2 m). The top blocks of the pyramids are connected to each other by steel wires for suspension of cylindrical nylon nets and baskets for mussel and oyster culture.

The second artificial reef was established in 1987, about 15 miles north of Ancona, in an area with sandy shores and sandy bottom which gradually changes to muddy as the depth increases. Before the construction of the reef the only natural banks of mussels present in the area were on breakwaters at about 300 m offshore, in waters where fishing is forbidden for health reasons.

Table 1 - Total mollusc production (cephalopods excluded) of the Mediterranean region (Fishing area 37) for 1987 (F.A.O., 1989a) in metric tons.

	Oysters	Mussels	Scallops Pectens	Clams	Others Molluscs	TOTAL
Albania	-	1,330	-	-	-	1,330
France	8,063	4,057	-	-	-	12,120
Greece	-	-	-	-	3,129	3,129
Italy	-	85,400	-	37,280	12,666	135,346
Lebanon	-	-	-	-	25	25
Morocco	-	164	-	-	12	176
Spain	88	833	-	2,795	218	3,934
Tunisia	-	-	-	-	1,172	1,172
Turkey	72	7,953	4	3,450	810	12,289
USSR	-	4,512	-	-	-	4,512
Yugoslavia	64	1,076	-	-	255	1,395
TOTAL	8,287	105,325	4	43,525	18,287	175,428

The reef is 1.2 miles offshore, on a sandy-muddy bottom, at a depth of 11 m, and consists of 29 pyramids, of the same kind as the Portonovo reef, placed in a rectangular area protected against illegal fishing by anti-trawling bodies.

The top blocks of pyramids are connected by steel wires and are surrounded by 4 concrete cylinders which increase the fish- protection effect and provide additional surfaces for the settlement of bivalve larvae.

Finally 12 concrete cages (4x5x6 m) for submerged and suspended shellfish culture, were immersed inside the area delimited by the pyramids.

MUSSELS

Two different techniques have been tested for suspended and submerged mussel cultures (Figure 2).

The first one, experimented from 1983 to 1987, mainly consists of three or four operations:

1) immersion of collectors for mussel larvae settlement;
2) recovery of seed from collectors and transfer into cylindrical nylon nets (44 mm mesh size);
3) optional thinning out and transfer of the mussels into cylindrical nylon nets with a larger mesh (68 mm);
4) harvesting of the commercial product.

In the Adriatic Sea, mussel spawning generally occurs from late-autumn until late-spring (Poggiani, 1968; Hrs-Brenko, 1980; Valli, 1980; Ceccherelli and Barboni, 1983; Fabi *et al.*, 1989).

Settlement of larvae reaches its highest intensity in spring, that seems to be the best period for immersion of collectors which, in our case, were nylon ropes that permit high mussel settlement and do not rot (Fabi *et al.*, 1985 and 1989).

The best depth for immersion of collectors is from 1 to 5 m under the sea surface, where the highest settlement density can be obtained (Fabi *et al.*, 1989).

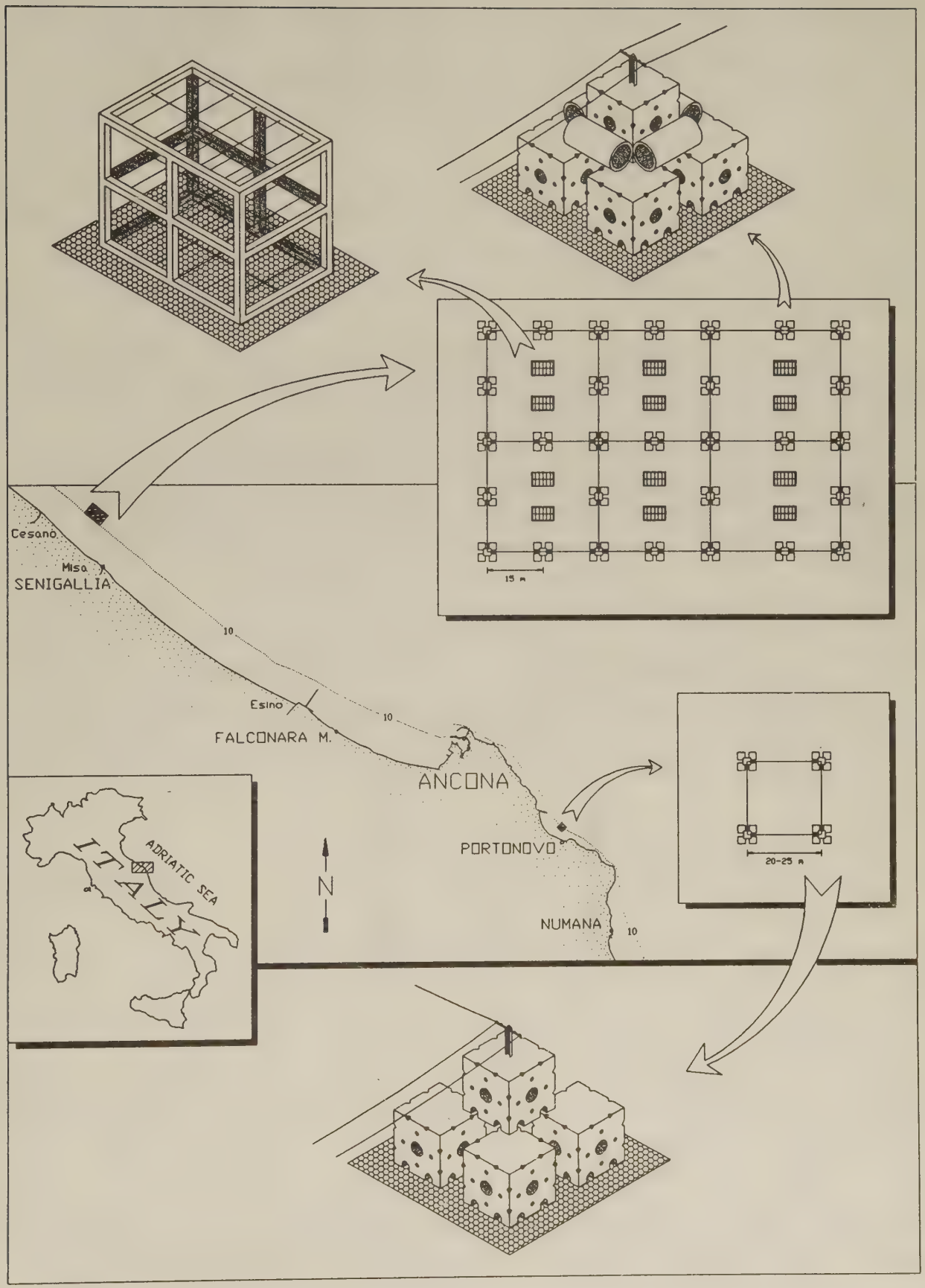

Figure 1 - Artificial reefs in which mussel and oyster culture experiments were carried out, and their locations.

Table 2 - Parameters of the seasonal V.B. length-growth equations.

	M.galloprovincialis	*O. edulis*	*C. gigas*
$L\infty$	85.45 ± 2.91	81.92 ± 1.37	96.20 ± 3.98
K	1.21 ± 0.11	1.21 ± 0.05	1.04 ± 0.09
T_o	0.46 ± 0.02	0.67 ± 0.01	0.66 ± 0.01
C	0.57 ± 0.08	1.27 ± 0.03	1.38 ± 0.04
T_s	0.51 ± 0.02	0.56 ± 0.01	0.59 ± 0.01

In autumn, the total length (TL) of the seed is between 35 and 40 mm with a biomass ranging between 10 and 15 kg per metre of rope, varying from year to year. This can be harvested and transferred into the cylindrical nylon nets suspended from the steel wires between the pyramids and from the concrete cages, for further growth.

Figure 3a shows the seasonal Von Bertalanffy (V.B.) growth curve in length for the mussels raised for two years in these conditions. The corresponding total weight curve (TW), computed on the basis of length V.B. and TW/TL regression equations (Tables 2 and 3), is reported in Figure 3b together with the raw data.

The length and weight increases slacken during the winter months because of low water temperature.

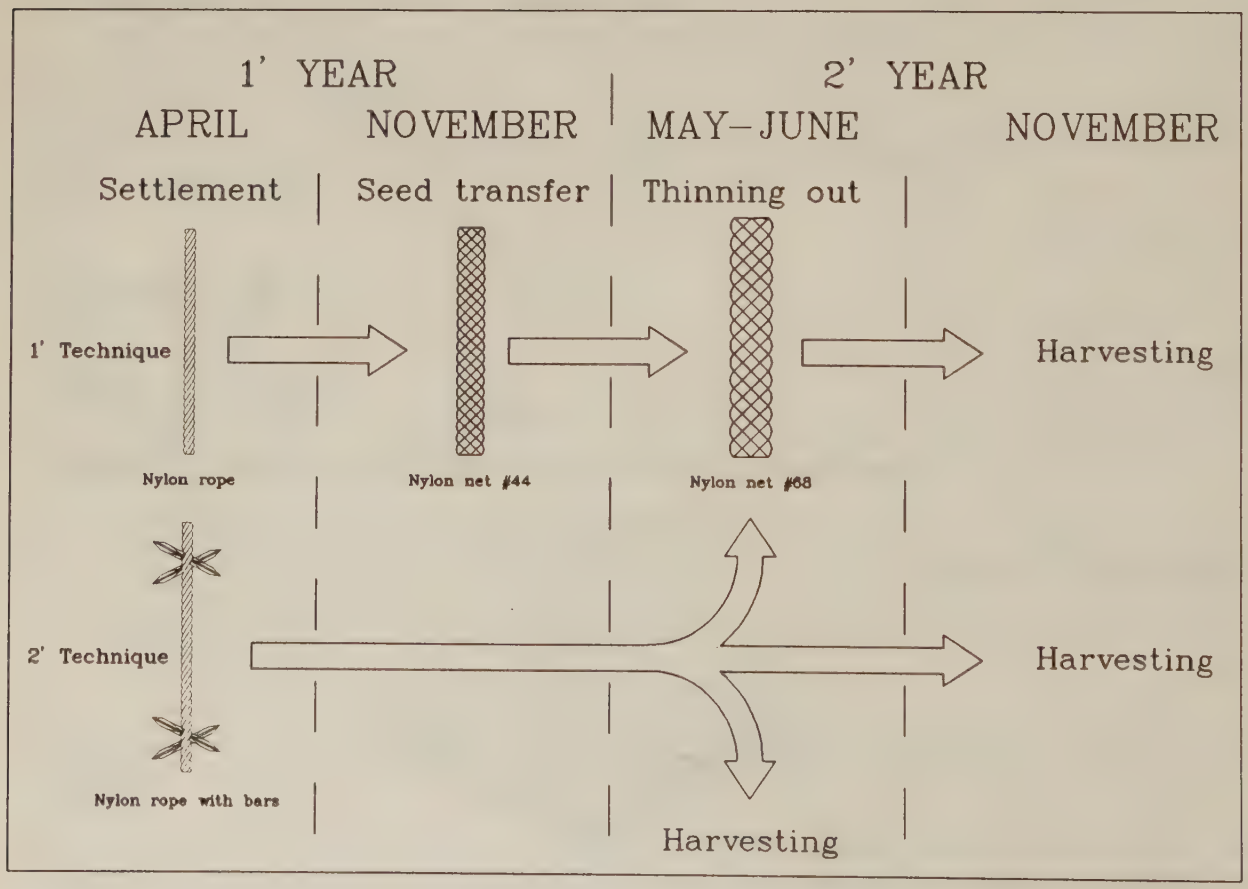

Figure 2 - Nylon ropes and cylindrical nylon nets used for mussel culture. The two different culture techniques are illustrated.

Table 3 - Parameters of the GM regression equations (Ricker, 1973) of total weight against total length (natural logarithms).

	M.galloprovincialis	*O. edulis*	*C. gigas*
a	- 9.704	- 9.747	- 9.570
b	3.054	3.179	3.147
r	0.995	0.997	0.998

During the farming period, large differences in survival may be observed, but an average loss of about 25% can be considered as usual, mainly due to the fact that the smallest specimens are not retained by the net mesh.

The following spring, about 50% of the mussels are marketable ($\overline{TL}$ > 50 mm) with an average commercial yield of about 2.4 kg per kg of seed placed initially in the nylon nets.

By thinning out the mussels once in late spring-early summer, by autumn all the mussels are over the commercial size ($\overline{TL}$ = 70 mm) and the yield is increased to 7 kg per kg of seed.

In order to obtain the best yield, harvesting can be started in autumn and continued during the winter months, when the fishing on natural banks is forbidden and high quantities of mussels are imported. In fact a further year of breeding do not seem convenient because of the reduction in growth rate, as well as of the additional work required and finally of possible losses of product caused by winter storms. Eventually, only a part of the mussels can be further on farmed in order to obtain a top-quality production.

The second technique has recently (1988-1989) been applied in order to reduce the underwater work required. It is similar to the culture techniques utilized in the Spanish "bateas": nylon ropes, intersected at 50-70 cm by small plastic bars, are used in order to prevent the mussels from sliding down the ropes as a result of excessive weight.

During the season of highest settlement intensity, these ropes are suspended from the steel wires between the pyramids and from the concrete cages. The mussel seed, which settles on these, is allowed to grow without further transfers or thinning out until the commercial size is reached.

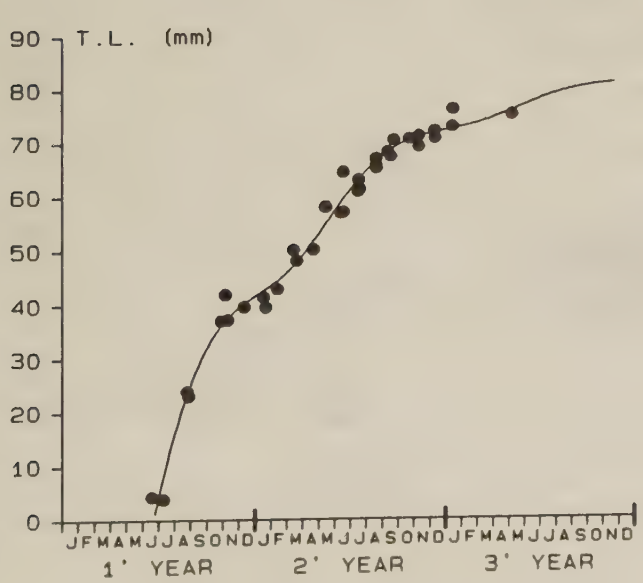

Figure 3a - Seasonal V.B. length-growth curve for mussel.

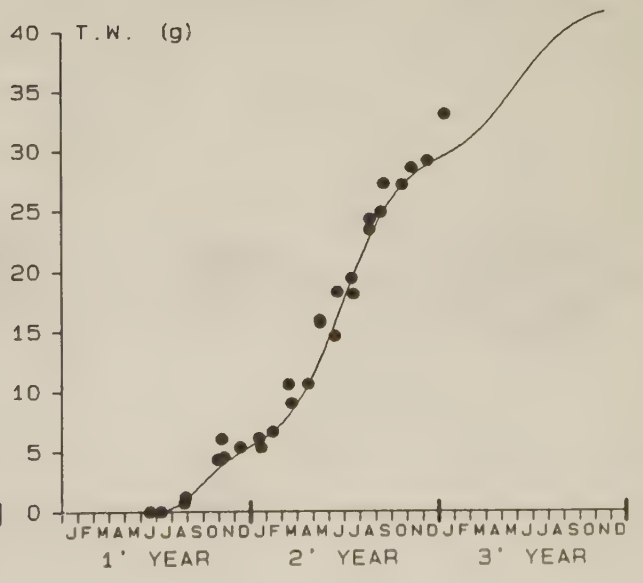

Figure 3b - Corresponding seasonal total weight curve.

During the first year, mussels raised using this technique seem to grow a little faster than in the case of the first technique described above (all specimens of commercial size in spring), but this difference is negligible in autumn ($\overline{TL}$ = 72 mm).

Higher losses are however observed as a result of mussels sliding down the ropes because of excessive weight. In fact, the production obtained after one year from immersion is about 8 Kg per meter of rope, and this does not increase six months later.

OYSTERS

The technique used for oyster culture (*O. edulis* and *C. gigas*) inside artificial reefs has been tested for four years, between 1986 and 1989, and consists of 4 or 5 phases (Figure 4):

1) Immersion of suitable collectors for settlement of larvae;
2) Recovery of the young oysters from collectors and transfer into suspended plastic baskets for breeding;
3) Transfer of oysters into baskets with larger holes;
4) Optional final phases of "fattening";
5) Harvesting of the commercial product.

Our investigations have shown that spawning for both oyster species occurs during summer months. Spat recruitment on the collectors occurs from late summer to early autumn with only a short period of maximum intensity (Fabi *et al.* 1989). But large differences over the years, both in intensity and in the period of the highest settlement, have been observed according to recordings along the French coasts for *O. edulis* (Paquotte *et al.*, 1987) and *Crassostrea angulata* (Le Dantec, 1968).

Plastic Pleno multituiles type (60x60x8 cm) collectors were chosen for spat recruitment for their high collecting surface (1.4 m^2). They are immersed at about 60 cm from the bottom in piles fixed on suitable iron structures.

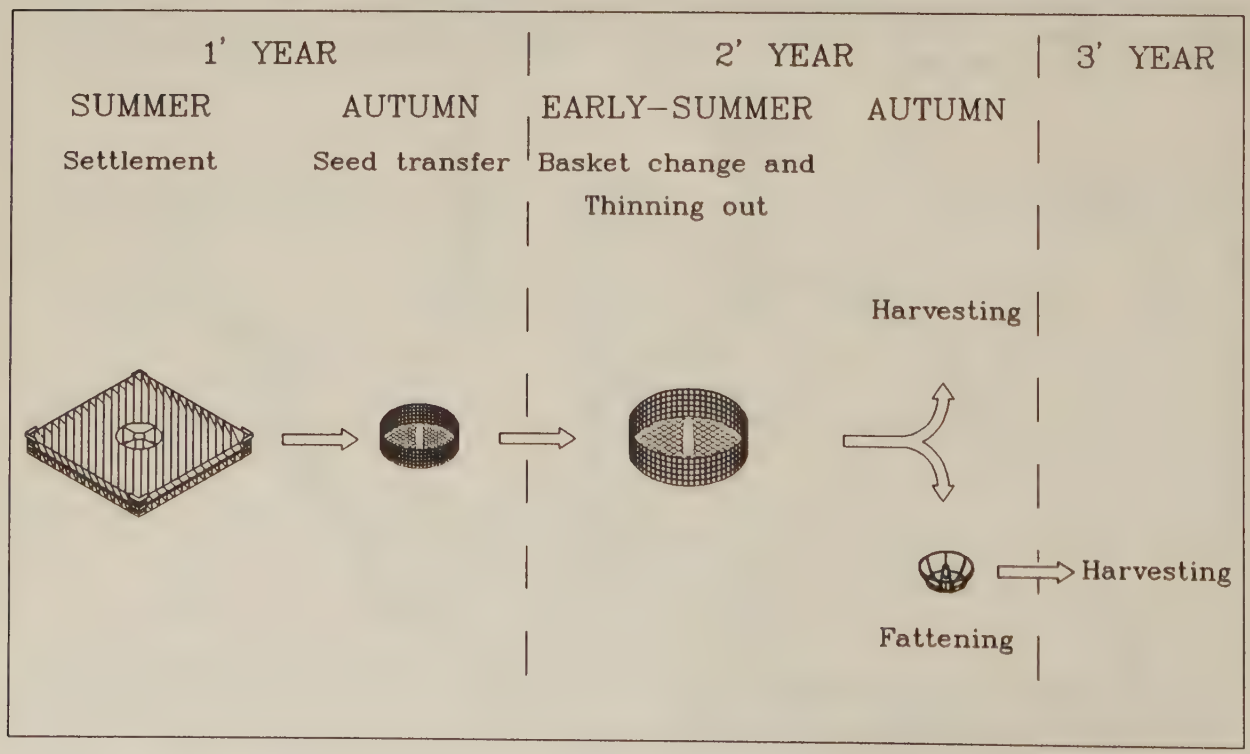

Figure 4 - Pleno multituiles type collectors and plastic baskets for oyster culture. The different culture phases are illustrated.

When the young oysters are about 20-30 mm, they may be taken from the collectors, placed in plastic baskets and then suspended from the submerged structures. The transfer from collectors into the baskets may result in loss or damage to some specimens that, in our case, were estimated to be about 20%.

In the early summer of the following year, the oysters must be transferred into baskets with larger holes in order to increase the water flow through the baskets and to reduce the possibility of obstruction by mussels and siltation.

Growth in length for the two oyster species is well represented by the seasonal V.B. curve (Figure 5a), calculated for a culture period of about 3 years. The corresponding total weight curve, computed on the basis of length V.B. and regression equations (Tables 2 and 3), is reported in Figure 5b together with the raw data.

Both of these species show a similar reduction in growth in length and weight during winter months, as shown by the C coefficients of the seasonal V.B. length growth equations, which are higher than in the case of mussels (Fabi *et al.*, 1989).

A slackened growth during the winter season is also reported for *O. edulis* culture along the Yugoslavian coast of the northern Adriatic (Hrs-Brenko, 1973).

At the end of the first year of suspended growth, the length and weight of the *C. gigas* are a little more than those of the *O. edulis*, though both species are over the commercial size (TL = 60 mm) and can be marketed at this time.

In order to obtain a product of top quality, cultivation may be continued for an additional period. In this case the oysters should be transferred into special baskets for "fattening" which have larger holes that ensure better water flow.

During suspended breeding, damage to the young oysters during the transfer from the collectors to the baskets and the reduced water flow through the baskets, as a result of fouling and siltation, above all in the summer months, may cause the death of some specimens. Moreover, occasional losses (ranging between 0 and 15% in our case) may occur because of basket damage.

Despite this, an average survival of about 75% may be considered as normal. After one year of breeding, the commercial yield that can be obtained for *O. edulis* is estimated at about 3 kg per 100 young specimens (or 270 g) placed in the baskets at the beginning, and about 4 kg after a further year. In the case of *C. gigas* the yield is estimated at about 4 kg and 6 kg respectively, per 100 young specimens (or 380 g).

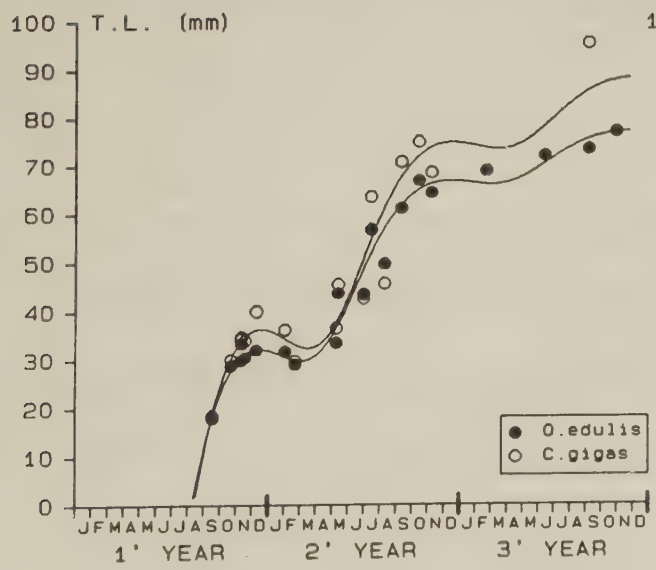

Figure 5a - Seasonal V.B. length-growth curves for *O. edulis* and *C. gigas*.

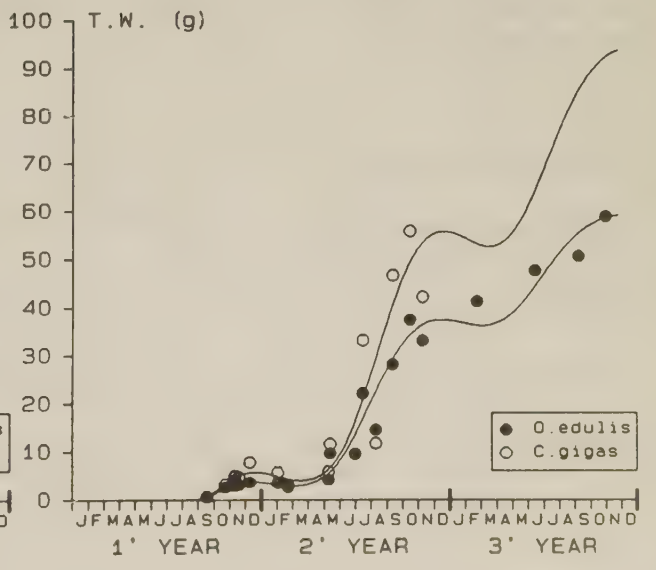

Figure 5b - Corresponding seasonal total weight curves.

CONCLUSIONS

In comparison to the traditional methods, the techniques for mussel and oyster culture described above require much more underwater work, but seem to be the most suitable for shellfish culture in open-sea areas exposed to storm and wave action.

Mussel culture on ropes with bars eliminates some of these operations and a part of the underwater work. There is no need, for example, to recover the collectors and transfer the seed into the cylindrical nylon nets. However, in order to reduce the losses of mussels, the product must be harvested as soon as it reaches commercial size (TL = 50 mm) or transferred into nylon nets in the second year of breeding. The final yield, however, is much lower than that obtained with the first culture technique.

Regarding oyster culture, the reintroduction of this activity, which in the past was extensive, would give a production of more regular shape and uniform size compared with that from natural banks, from which the low Italian production is currently derived.

Moreover, it would lead to a diversification of the mussel monocultures in order to reduce the economic damage eventually caused by parasitic diseases often fostered by the high specimen concentration inside the culture parks.

The large differences occurring in the oyster spat recruitment over the years, even in similar environmental conditions (area, time, water temperature, etc.), can strongly affect the yield, as in 1988 when it was impossible for us to start another culture because of a very low density on the collectors. In this case, it is possible to obtain oyster spat from hatcheries, not yet available in Italy, but which are widely used in other countries, such as France and England.

The breeding methods proposed have been applied in the last two years for the realization of large-scale shellfish cultures associated with artificial reefs along the Adriatic coast, as at Rimini, Cattolica and Portonovo, and for the planning of other parks.

The development of such initiatives may not only satisfy the high Italian shellfish demand with the production of high quantities of top-quality product during all the year, but it may also contribute to a better management of the coastal area and to reducing the fishing effort by employing a part of this in alternative activities such as shellfish culture.

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COLONISATION PATTERNS OF HARD SUBSTRATA IN THE LOANO ARTIFICIAL REEF (WESTERN LIGURIAN SEA)

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INTRODUCTION

During the GFCM Technical Consultation on Open-Sea Shellfish Culture in Association with Artificial Reefs, held in 1986 at Ancona, we described the artificial reef of Loano (Relini and Moretti, 1986). Now we should like to provide some information about the colonization patterns of hard substrata on the basis of studies carried out using atoxic panels and the observations of scuba-divers and of photographs. We consider it of interest to report our data because the communities settled on blocks immersed at Loano are not dominated by mussels (M. galloprovincialis), as described in the Ancona artificial reef (Bombace 1981) and at Fregene (Ardizzone and Bombace 1983, Ardizzone et al. 1989).

MATERIALS AND METHODS

In the central part of the Loano artificial reef the following four stations at different depths were chosen (Fig. 1):

St. 1 at 5 m depth, one rack with four differently exposed frames
St. 2 at 10 m depth, one frame
St. 3 at 18-20 m depth, one rack as in st. 1
St. 4 at 30-36 m depth, one frame as in st. 2.

Each frame contained 5 panels (asbestos 30x20x0.4 cm) which were changed, respectively, every month, 3 months, 6 months, 9 months and 12 months from May 1987 to May 1988. A second year's observations from May 1988 to May 1989 concerned periods of exposure of 3, 6, 9, 12 months. A third cycle is in progress with a reduced number of panels at stations 1 and 3 because the settlement when there were four exposures was not significantly different; only two exposures have therefore been maintained.

When they were recovered the panels were photographed, weighed (for wet weight of fouling) and then the settlement was analysed in the laboratory.

Scuba divers took photographs of the colonization of blocks and also took samples from the standard surfaces.

RESULTS

For the panels a preliminary list of macrobenthic

species is reported in Table 1 and wet weights in Table 2. In general, the settlement on monthly panels is light; the highest weight was 50 g/per panel, i.e. about 6 g/dm^2. The maximum weight found on annual substrata was about 300 g (25 g/dm^2). This value of 2.5 kg/m^2 is very far from that found in the Adriatic Sea: 80 kg/m^2 of mussels after one year.

At Loano the community is much more diversified: slime, small algae, hydroids (Clytia, Obelia, Bougainvillia etc.), serpulids (Hydroides, Pomatoceros, Serpula, Spirobranchus), barnacles (Balanus perforatus, B. trigonus) and some bryozoans are the main colonizers of substrata after one month's exposure. These are followed by algae, other bryozoans, bivalves, ascidians, sponges on the three- and six-month immersion panels.

After a year there is evidence of intense settlement of large colonies of bryozoans (Schizoporella errata) with hydroids and algae on the panels of all periods of exposure at station 1 and on both sides of each panel. Almost the whole surface is occupied with encrustations of these bryozoans which partly cover other organisms such as barnacles, serpulids, bivalves. ascidians and ctenostomata bryozoans are also present. Mussels and oysters are quite rare.

At station 2, bryozoans are still the dominant organisms although the space they occupy is smaller than that on station 1. At station 2, as also at station 4, the panels were placed virtually in contact with the block; the result was that the two sides received different exposure to the light and thus the colonization is different. There is an absence of alga on the side indicated as "number two" and a greater quantity of spirorbidae, barnacles, ascidians and bivalves.

At station 3 the surface area occupied by encrusting bryozoans is smaller, whereas that occupied by serpulids and hydroids is larger.

Station 4 suffered various types of damage caused by trawlers.

As far as the colonization of the blocks is concerned, we can say that two years after immersion in the sea, all the blocks prove to have a high degree of colonization, qualitatively and quantitatively. At station 1 in particular the settlement is made up of a well-developed cover of alga. Photophilic alga dominate, in particular Dictyota. There is also an abundance of bryozoans (especially Schizoporella) and serpulids (Salmacina, Serpula, Pomatoceros etc.).

At station 2 the share of alga is reduced and that of animals increases. There are also numerous ascidians, sponges and hydroids. The whole surface appears colonized.

At station 3 the quantity of alga is further reduced. The dominant species are serpulids, hydroids, bryozoans and good-sized oysters. Large groups of

Table 1 - List of the main macrobenthos species

ALGAE	Rhodophyta	Polysiphonia subulata (Ducluzeau) J. Agardh
		Polysiphonia variegata (C. Agardh) Zanardin
		Porphyra umbilicalis (Linnaeus) J. Agardh
		Stylonema alsidii (Zanardini) Drew
		Stylonema cornu-cervi Reinsch
		Ceramium flaccidum (Kutzing) Ardissone
		Lophosiphonia scopulorum (Harvey) Womersley
	Phaeophyta	Ectocarpus confervoides (Roth) Kjellman var siliculosus (Dillwyn) Kjellman
		Ectocarpus siliculosus (Dillwyn) Lyngbye va arctus (Kuetzing) Kjellman
		Sphacelaria cirrosa (Roth) C. Agardh
		Cutleria monoica Ollivier
		Cutleria adspersa (Mertens) De Notaris
		Dictyopteris membranacea (Stackhouse) Batte
		Spermatochnus paradoxus (Roth) Kutzing
		Dictyota dichotoma (Hudson) Lamouroux
	Chlorophyta	Bidingia minima (Nageli e Kutzing) Kylin
		Cladophora sp.
PORIFERA		Sycon sp.
CNIDARIA	Hydroida	Bougainvillia ramosa (Van Beneden 1844)
		Clytia gravieri (Billard 1904)
		Clytia hemisphaerica (L. 1767)
		Gonothyraea loveni (Allman 1859)
		Laomedea angulata (Hincks 1859)
		Laomedea calceolifera (Hincks 1871)
		Obelia bidentata Clarke 1875
		Obelia geniculata (L. 1758)
		Obelia longissima (Pallas)
		Orthopyxis integra (Mac Giltivray)
		Plumularia setacea (L. 1758)
		Sertularella gaudichaudi (Lamouroux 1824)
		Tubularia crocea Agassiz 1862
ANNELIDA	Polychaeta	Hydroides pseudouncinata pseudouncinata Zibrowius 1971
		Hydroides elegans (Haswell 1883)
		Pomatoceros lamarckii (Quatrefages 1865)
		Pomatoceros triqueter (Linnaeus 1767)
		Semivermilia cribrata (O.G. Costa 1861)
		Serpula concharum Langerhans 1880
		Serpula vermicularis Linnaeus 1767
		Spirobranchus polytrema (Philippi 1844)
		Spirorbide
ARTHROPODA	Cirripedia	Balanus amphitrite Darwin 1854
		Balanus eburneus Gould 1841
		Balanus perforatus Bruguiére 1789

		Balanus trigonus Darwin 1854
		Verruca stroemia (O.F. Muller) 1776
	Amphipoda	Atylus massiliensis Bellan Santini 1974
		Dexamine spinosa (Montagu 1813)
		Jassa marmorata Holmes 1903
		Phtisica marina Slabber 1778
MOLLUSCA	Bivalvia	Mytilus galloprovincialis Lam 1819
		Ostrea edulis L.
		Anomia ephippium Linnaeus 1758
		Musculus marmoratus (Forbes)
		Hiatella rugosa (L.)
BRYOZOA	Cheilostomata	Schizoporella errata (Waters 1848)
		Chorizopora brongniartii (Audouin 1826)
		Cryptosula pallasiana (Moll 1803)
		Electra monostachys (Busk 1854)
		Turbicellepora magnicostata (Barroso 1919)
		Aetea truncata (Landsborough 1852)
		Escharina vulgaris (Moll 1803)
		Lichenopora radiata (Audouin 1826)
		Microporella ciliata (Pallas 1766)
		Umbonula ovicellata (Hastings 1944)
		Fenestrulina malusii (Audouin 1826)
		Schizomavella auriculata (Hassal 1842)
		Eurystrotos sp.
		Sertella sp.
	Ctenostomata	Bowerbankia gracilis (Leidy 1855)
ASCIDIACEA	Aplousobranchiata	Clavelina lepadiformis (Muller 1776)
		Didemnum maculosum Milne-Edwards 1842
		Didemnum granulosum (Von Drasche 1883)
	Stolidobranchiata	Botryllus schlosseri (Pallas 1776)
		Pyuridae

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serpulids are to be found and, in some months, there are nests of cephalopods even outside the holes.

Two phenomena are worthy of particular attention: the presence of large oysters and the activity of the sea-urchins Paracentrotus lividus and Arbacia lixula in cleaning the substratum. Large surfaces are completely cleaned and freed for new colonizers. Only oysters and large barnacles can withstand this activity of the echinoids. In our opinion, the oyster is a possible exploitable resource and we wish to improve our knowledge of settlement periods and growth rates with the aim of suggesting that this bivalve be cultivated locally.

Table 2: Wet weights grams of fouling settled on panels exposed for 1 month (A) and 2, 3, 6, 9, 12 months (B).

A		J	J	A	S	O	N	D	J	F	M	A	M
STAT. 1	A	35	.	.	30	.	31	40	1	43	30	.	22
	B	39	.	5	35	21	22	35	2	25	28	50	33
	C	39	.	5	.	24	32	33	2	42	28	45	30
	D	73	22	.	.	25	24	38	5	24	25	43	29
STAT. 2		28	.	12	40	20	16	24	2	20	13	48	11
STAT. 3	A	30	.	20	33	10	25	25	2	16	20	21	25
	B	32	.	27	30	10	23	24	2	15	18	20	13
	C	26	.	25	34	12	25	28	1	17	20	22	26
	D	25	.	24	33	10	31	25	5	17	20	22	21
STAT. 4		22	.	5	.	.	.	.	.	7	3	5	15

B		2 m	3 m				6 m		9 m	12 m
		J	A	N	F	M	N	M	F	M
STAT. 1	A	.	40	.	90	51	.	.	40*	.
	B	.	52	49	93	43	.	211	185	240
	C	.	40	.	.	74	.	.	193	.
	D	.	43	19	82	91	83	210	191	216
STAT. 2		51	42	53	46	60	66	276	175	315
STAT. 3	A	39	40	40	40	58	89	240	195	269
	B	44	50	36	50	56	109	230	185	264
	C	47	39	40	40	67	78	278	207	225
	D	47	38	35	39	48	66	278	159	276
STAT. 4		28	30	.	.	25	.	.	.	.

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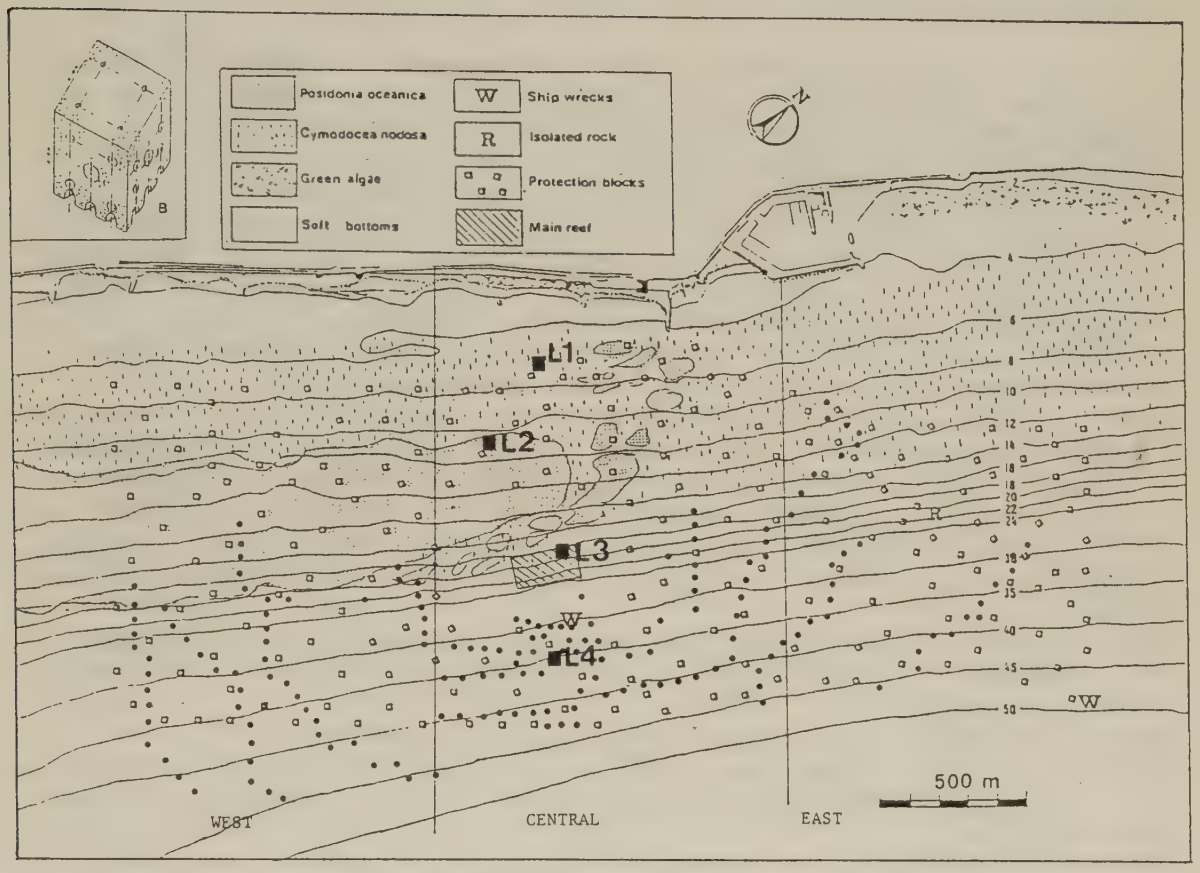

Fig. 1: Stations (L1, L2, L3, L4) used for the settlement study at Loano artificial reef.

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ARTIFICIAL REEFS IN THE LIGURIAN SEA: a report on the present situation

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INTRODUCTION

In the protection and management of shallow-water marine enviroments, artificial reefs could play an important role because of their contribution to 1) recycling the energy discharged into the sea in the form of organic wastes; 2) offering hard substrata suitable for settlement; 3) protecting marine biocoenoses, such as Posidonia beds, and small-scale fishing against trawlers; 4) offering shelter and protection to eggs, juveniles, moulting animals etc. (Bombace, 1981). All these roles, which are by now generally acknowledged, are at present a reality in the Ligurian Sea.

The aim of this paper is to provide information on the progress of artificial reefs along the Ligurian coast, to update previous information, and to report on the available bibliography.

The present situation (November 1989) with regard to artificial reefs in the Ligurian Sea is as follows (Fig. 1):

a) constructed: Varazze (car-bodies and wooden barges), Golfo Marconi (various materials), Loano (concrete blocks);
b) under construction: Ventimiglia, Spotorno.
c) planned: Lavagna, Celle Ligure, Varazze, Pietra Ligure, Alassio, Laigueglia, S.Bartolomeo, Diano Marina.

VARAZZE

The first artificial reef in Italy, and therefore in the Ligurian Sea, was made in December 1970 near Varazze by a sports-fishing club which obtained permission, without any scientific support, to sink 1300 car-bodies in order to prevent trawling and to improve sports fishing in an area between 35 and 50 m depth.

The cars were soon subject to heavy corrosion and started to sink into the mud and to be covered with sediment (Relini and Relini Orsi, 1971). The settlement of organisms and sport fishing remain poor (Relini and Wurtz, 1977; Relini, 1979, 1982b, 1983a,b).

On the basis of our studies (1971), which showed poor results and pollution problems, the use of car-bodies and similiar waste materials for the purpose of creating artificial reefs has been banned by the Ministero della Marina Mercantile. In 1979, 16 wooden

barges were immersed close to the car-bodies and comparison of the two types of structure was possible. Barges proved to be more effective than car-bodies in preventing trawling, to be more attractive for fishes, and more suitable substrates for settlement. Nevertheless, wooden materials are subject to destruction by marine wood borers, so it is the fate of these barges to disappear. Recent scuba-diver observations and photographs have confirmed the ongoing destruction of the car-bodies and the wooden barges.

MARCONI GULF

Thanks to cooperation between Genoa University (Laboratori di Biologia Marina ed Ecologia Animale) and the Consorzio Golfo Marconi (an association of fishing clubs and small-scale fishermen from Rapallo and S. Margherita Ligure), artificial reefs were constructed in the Marconi or Tigullio Gulf from 1980 to 1985 (Relini 1982a, 1984). Wooden barges, concrete blocks, dock-gates made of timber and iron, loose materials (sand, gravel, coarse pebbles) were used so that, by 1984, the artificial reefs had reached a volume of 16,185 m^3, with a surface available for organism settlement of 9,234 m^2 covering a bottom of 2.1 km^2 and protecting at least another 6 km^2 of the Gulf (Relini et al., 1986).

Sports fishing clubs (Circolo Pescatori Dilettanti Rapallesi, Lega Navale Italiana di Rapallo, Società Pescatori Dilettanti di S. Margherita Ligure) in the Marconi Gulf think that the construction of artificial reefs has improved the quality of their activity and the quantity of their official fishing competitions using lines. The summer competitions showed increasing catches in terms of weight of fish per fishermen and per trip from 1982 to 1986 despite the increased number of participants in each competition (Relini & Orsi Relini 1989). In 1987 a marked decrease in catches occurred although some individual results were still good. The positive trend reappeared in 1988.

Scuba-diver observations have confirmed a high diversity of communities settled on different substrata, but they also reported damage to the wooden barges. The immersion of suitable new structures to mantain the benefits of this artificial reef is recommended.

LOANO

In the summer of 1986 the artificial reef at Loano was built in a area of about 350 ha between 5 and 45 metres depth, with the aim of protecting and restoring a Posidonia oceanica bed destroyed by illegal trawl fishing and the discharge into the sea of muddy material (Relini and Moretti, 1986).

Here the artificial reef was originally composed of two parts (Fig. 2): a central main group of 30

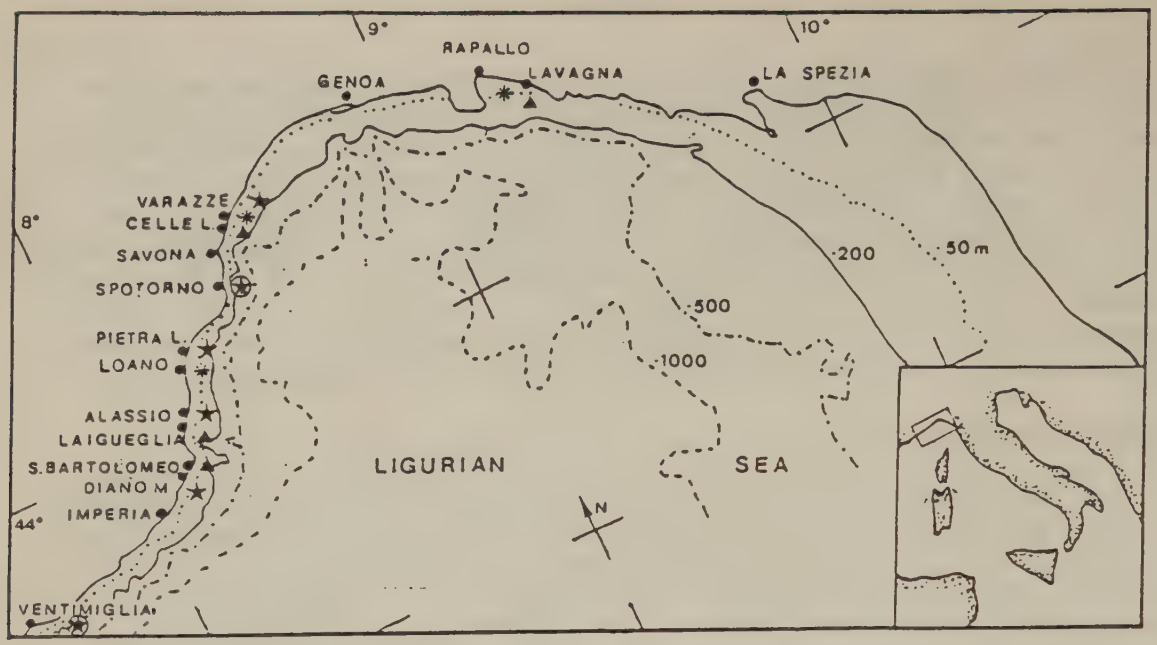

Fig. 1: Distribution of existing artificial reefs (asterisk), in construction (encircled star), approved plans (star), plans (triangle).

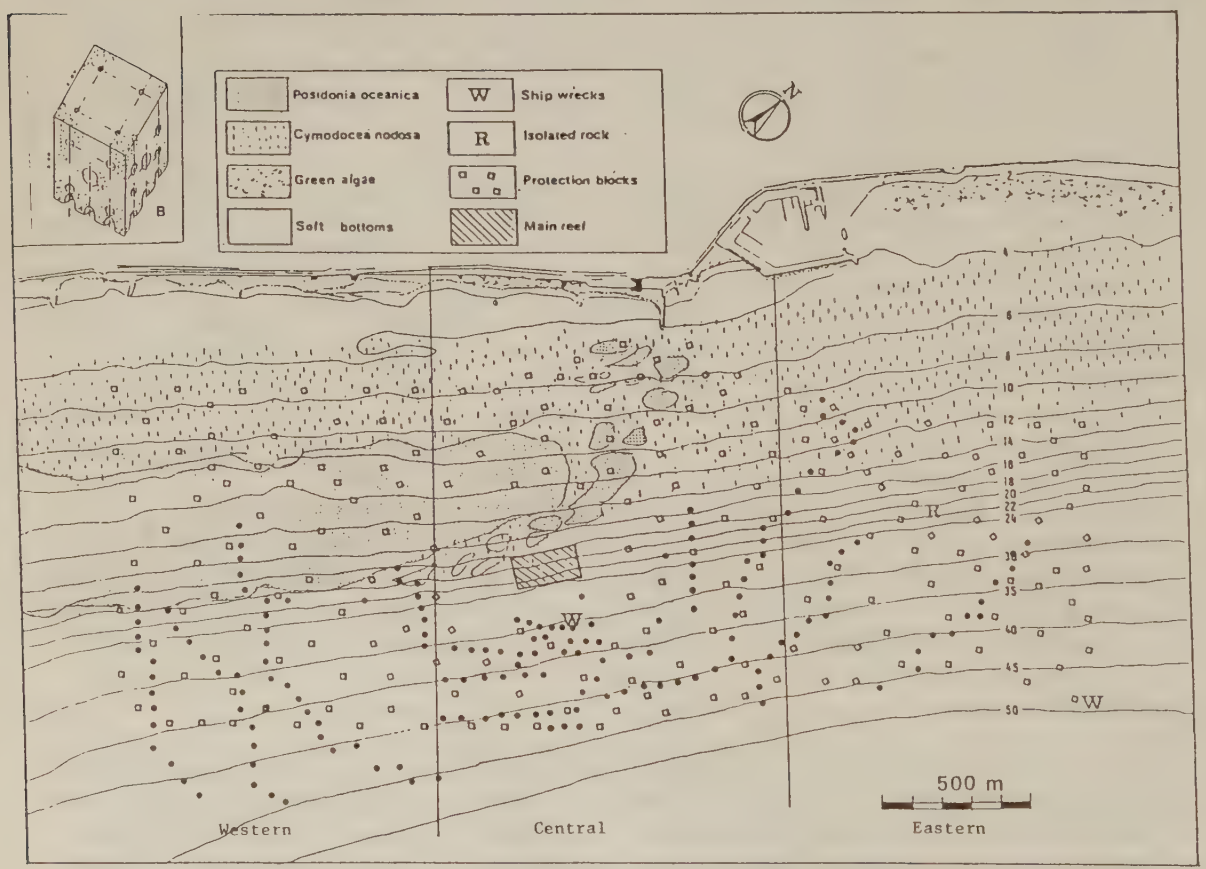

Fig. 2: Loano - A general view of the location of the main reef and distribution of blocks protecting Posidonia beds (small blocks open square, large blocks B immersed in 1989 are represented by black dots.). Three areas for fish census (western, central, eastern) are indicated.

pyramids, 25 m apart, positioned along the sides of and inside a 100x200 m rectangle. Each pyramid was arranged in four blocks (cubic block of 2m side) at the base and one at the top positioned on a 50 cm layer of stone to prevent the structure from sinking into the bottom.

The second part was composed of a grid of 200 single blocks (cubic blocks of 1.2 m side) distributed in a rectangle of about 3x1.5 km in such a way as to prevent any passage wider than 250x50 m. The aim was to prevent trawling in the area while allowing the use of artisanal gear.

Unfortunately, however, although each of these blocks weighs 3 t, they have been moved by trawlers.

Thanks to a saving of funds it was possible to immerse a new series of 150 big blocks (2m at the edge) which were distributed as indicated in Figure 2 in such a way as to reinforce the protection of the central restocking zone and the most external part of the area where the small blocks were positioned.

For over two years now, studies have been carried out into colonization and settlement of organisms. These have supplied interesting data which have been reported in another paper in this volume. On the orders of the Savona Port Authority the whole area is covered by a ban on any form of sampling with the exception of that carried out for research purpose. Since there was also a request for information on the progress of the resources, it became necessary to ask for the collaboration of the local fishing cooperative. The whole area was divided into three zones: east, central, west. In the central zone the fishing ban is still in force, but unfortunately it is not respected. The east and the west zones, on the other hand, have been opened alternately to fishing to a limited group of authorized people who are obliged to fill out special forms.

With regard to fishing and the census of fish by scuba-divers, we refer the reader to another paper (Relini G., Relini M. and G. Torchia, in this volume).

PROJECTS

In 1986 six artificial reef projects along the western Ligurian coast were planned by a professional engineering association in Savona.

These are: Varazze (protected area: 136 ha) to the east of the car-bodies; Spotorno (167 ha); Pietra Ligure (211 ha); Alassio (168 ha); Diano Marina (153 ha), Ventimiglia (256 ha). Two of these, Spotorno and Ventimiglia, have received financial support from the European Economic Community and are under construction.

In each zone the protected area will be surrounded by 50 steel piles (diameter 40 cm) implanted vertically in the bottom three metres in and three metres out. Inside this area 21 big modules (prefabricated concrete structures 6x6x4.5 m, 160 m^3, 27 t composed of 13

independent panels assembled on land) and 602 small modules (1.25x1.25x1.25 like a cubic box with 4 sides each perforated by a triangular opening) will be assembled.

The above-mentioned structures are of the "BONNA" type used in France by the C E P R A L MAR (Centre d'Etude et de la Promotion des Activites Lagunaire et Maritimes) along the Languedoc - Roussillon coast.

In Spotorno the artificial reef called "fish restocking zone" is an area of about 167 ha (approx. 1500x1000m) delimited by a double row of steel piles or concrete blocks with piles positioned 170 m apart. Inside the area, seven groups of modules are planned. The groups are sited 200 m apart between 18 and 32 m depth. Each group is made up of three big modules positioned at the vertices of an equilateral triangle of 50 m side. Inside this triangle the small modules are assembled in 14 pyramids each made up of 6 pieces.

The Spotorno artificial reef is under construction: 17 large structures have been positioned in the last few months.

OTHER PLANS

Plans have been presented for S. Bartolomeo, Laigueglia and Celle Ligure (western Riviera) and for Lavagna (eastern Riviera).

CONCLUSIONS

On the basis of results and observations made in the Ligurian Sea we are of the opinion that artificial reefs are an effective instrument in the management of the coastal zone; however, it is not the only one available and is not necessarily suitable for all types of environment.

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FISHES OF THE LOANO ARTIFICIAL REEF
(Western Ligurian Sea)

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Introduction

The study of the mobile fauna associated with an artificial reef touches on a great number of interests which range from the ethology of the organisms to the problems of production and exploitation. Underwater observation can represent an effective method in the process of understanding the dynamics of population establishment. Direct censuses however do not cover the entire fish population as some species remain concealed to the scuba diver. Fishing activities may provide the opportunity to complete the census.

30 months after its construction (Relini and Moretti 1986), the Loano artificial reef saw the start of a study of the fish abundance with censuses at monthly intervals. The results of 10 months of observations are completed with the results of limited fishing activity using longlines and trammels.

Materials and methods

This study sets out to examine the fish population inside the Loano artificial reef using two different techniques:

a) the study of data provided by professional fishermen who have obtained a fishing permit for the purpose of supplying information on the resources.
b) direct censuses conducted by scuba divers (M.Relini and G.Torchia).

From 1.1.89 to 14.9.89 some members of the local fishing cooperative filled out specially prepared forms for a total of 191 catches, 33 of which were made using longlines and 158 using trammels. These provided both qualitative and quantitative data (species, number of individuals, weight and size) on the catches outside the pyramids. Dives were carried out at least at monthly intervals; 16 were diurnal (11.2, 28.3, 31.3, 24.4, 17.5, 9.6, 14.6, 1.7, 12.7, 6.8, 30.8, 5.9, 30.9, 12.10, 26.10, 14.11) and two nocturnal (20.5 e 12.10).

The underwater observations were carried out by two divers using the Harmelin method (Harmelin-Vivien et al. 1985).

The scuba divers explored an area of 312 m^2 inside the artificial reef including two pyramids each making up 40 m^3 of the artificial substrata.

The census comprises two phases. Once the diver has reached the apex of the pyramid the observer counts the fish moving around him for 15 minutes. Then he moves to the base of the structure in order to explore the holes and the internal corridors. The second phase consists of a 25 m crosswise movement to reach another pyramid, where phase a) is then repeated.

Table 1 Species observed and/or caught

		DIVE	TRAMMEL	LONGLINE
1	Apogon imberbis (Linnaeus 1758)	*		
2	Blennius rouxi Cocco 1833	*		
3	Boops boops (Linnaeus 1758)	*	*	
4	Chromis chromis (Linnaeus 1758)	*		
5	Conger conger (Linnaeus 1758)	*		*
6	Coris julis (Linnaeus 1758)	*		
7	Dentex dentex (Linnaeus 1758)	*	*	*
8	Dicentrarchus labrax (Linnaeus 1758)	*	*	*
9	Diplodus annularis (Linnaeus 1758)	*	*	
10	Diplodus puntazzo (Cetti 1777)	*		
11	Diplodus sargus (Linnaeus 1758)	*	*	*
12	Diplodus vulgaris (E.Geoffroy St.Hilaire 1817)	*	*	
13	Gobius sp.	*		
14	Homarus gammarus (Linnaeus 1758)	*		
15	Mugil sp.	*	*	
16	Mullus surmuletus Linnaeus 1758	*	*	*
17	Mycteroperca rubra (Bloch 1793)	*		
18	Oblada melanura (Linnaeus 1758)	*		
19	Octopus vulgaris Cuvier 1797	*	*	*
20	Pagellus sp.	*	*	
21	Palinurus elephas (Fabricius 1787)	*		
22	Sciaena umbra Linnaeus 1758	*		
23	Scorpaena notata Rafinesque 1810	*	*	*
24	Scorpaena porcus Linnaeus 1758	*	*	*
25	Scorpaena scrofa Linnaeus 1758	*	*	*
26	Scyllarus arctus (Linnaeus 1758)	*	*	
27	Sepia officinalis Linnaeus 1758	*	*	
28	Serranus cabrilla (Linnaeus 1758)	*		
29	Serranus hepatus (Linnaeus 1766)	*		
30	Spicara maena (Linnaeus 1758)	*	*	
31	Spicara smaris (Linnaeus 1758)	*	*	
32	Spondyliosoma cantharus (Linnaeus 1758)	*		
33	Symphodus mediterraneus (Linnaeus 1758)	*	*	
34	Symphodus tinca (Linnaeus 1758)	*	*	
35	Arnoglossus sp.		*	
36	Ilex coindetii (Verany 1839)		*	
37	Lithognathus mormyrus (Linnaeus 1758)		*	*
38	Loligo vulgaris Lamarck 1798		*	
39	Merluccius merluccius (Linnaeus 1758)		*	
40	Mullus barbatus Linnaeus 1758		*	*
41	Murena helena Linnaeus 1758			*
42	Pagrus pagrus (Linnaeus 1758)		*	*
43	Sarda sarda (Bloch 1793)		*	
44	Scomber japonicus Houttuyn 1780		*	
45	Scophthalmus rhombus (Linnaeus 1758)		*	
46	Seriola dumerili (Risso 1810)		*	*
47	Serranus scriba (Linnaeus 1758)		*	*
48	Sparus aurata Linnaeus 1758		*	
49	Squilla mantis (Linnaeus 1758)		*	
50	Trachinus sp.		*	*
51	Trachurus sp.		*	
52	Triglidae		*	
53	Umbrina cirrosa (Linnaeus 1758)		*	*
54	Uranoscopus scaber Linnaeus 1758		*	
55	Zeus faber Linnaeus 1758		*	

Results

a) species observed and/or fished

Using the data supplied by the fishermen and the counts carried out by scuba divers 55 taxa were recorded: 49 fishes, 3 crustaceans decapods and 3 cephalopods (table 1).

Thirthyfour species (61.8% of the total) were recorded in the underwater census, 39 (70.9%) using trammels and 17 (30.9%) using longlines.

Since trammel fishing generally covers almost all fishes (Spanier et al.1985), the catch records appear somewhat poor.

b) Artisanal fisheries

A summary of the progress of total catches using trammels and longlines in the eastern part of the reef is to be found in figures 1 and 2; (we have not received the fishermen's data for the trammels in April and May nor for the longlines in May; Figs. 1 and 2).

When one analyses the catches in detail one notes that there was a significant qualitative change in them after the spring with an increase in the number of species. There was, however, a decrease in the quantities of some of the main species (octopus, cuttlefish etc.) which constituted a large percentage of the catch in the first period (Table 2, Figs. 3 and 4).

Fig.1
Loano artificial reef
trammel catches

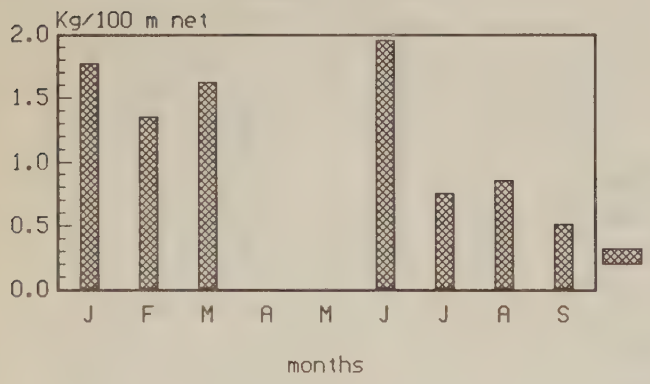


Fig.2
Loano artificial reef
longline catches

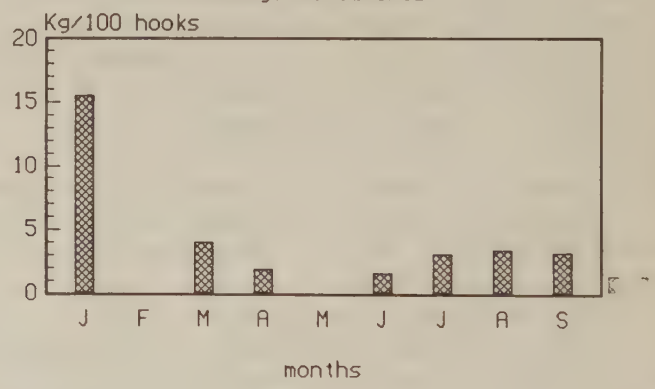
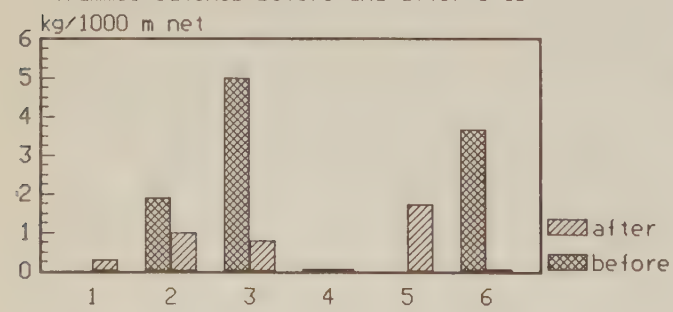
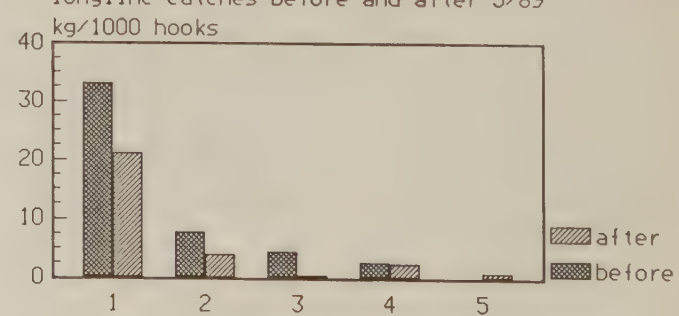


Fig.3
Loano artificial reef
trammel catches before and after 5/89



1=Uranoscopus 2=Diplodus 3=Octopus
4=Dicentrarchus 5=Scorpaena 6=Sepia

Fig.4
Loano artificial reef
longline catches before and after 5/89



1 = Conger 2 = Diplodus 3 = Octopus
4 = Dicentrarchus 5 = Scorpaena

Table 2 Catch composition during the year.

		Trammel kg/1000 m net		Longline kg/1000 hooks	
		Jan-Mar	Jun-Sep	Jan-Ap	Jun-Sep
1	Arnoglossus sp.	0.49	0.52	-	-
2	Boops boops (Linnaeus 1758)	0.06	0.38	-	-
3	Conger conger (Linnaeus 1758)	-	-	33.14	21
4	Dentex dentex (Linnaeus 1758)	0.40	0.03	0.32	-
5	Dicentrarchus labrax (L. 1758)	0.04	0.06	2.6	2.35
6	Diplodus sp.	1.89	0.97	7.7	3.79
7	Ilex coindetii (Verany 1839)	-	0.14	-	-
8	Lithognathus mormyrus (L. 1758)	0.64	0.28	-	0.1
9	Loligo vulgaris Lamarck 1798	0.25	-	-	-
10	Merluccius merluccius (L. 1758)	0.32	0.11	-	-
11	Mugil sp.	0.33	0.15	-	-
12	Mullus surmuletus Linnaeus 1758	0.70	1.87	-	0.01
13	Murena helena Linnaeus 1758	-	-	-	0.09
14	Octopus vulgaris Cuvier 1797	4.99	0.79	4.42	0.34
15	Pagellus sp.	0.23	-	-	-
16	Pagrus pagrus (Linnaeus 1758)	-	0.10	-	0.12
17	Sarda sarda (Bloch 1793)	0.03	-	-	-
18	Scomber japonicus Houttuyn 1780	0.25	-	-	-
19	Scophthalmus rhombus (L. 1758)	0.15	0.03	-	-
20	Scorpaena sp.	-	1.72	-	0.7
21	Scyllarus arctus (Linnaeus 1758)	-	0.005	-	-
22	Sepia officinalis Linnaeus 1758	3.64	0.06	-	-
23	Seriola dumerili (Risso 1810)	-	0.05	-	0.23
24	Serranus scriba (Linnaeus 1758)	-	-	-	0.54
25	Sparus aurata Linnaeus 1758	-	0.05	-	-
26	Spicara sp.	-	0.06	-	-
27	Squilla mantis (Linnaeus 1758)	-	0.06	-	-
28	Symphodus sp.	0.07	-	-	-
29	Trachinus sp.	-	0.01	-	-
30	Trachurus sp.	0.23	0.32	-	-
31	Triglidae	-	0.08	-	-
32	Umbrina cirrosa (Linnaeus 1758)	0.14	-	-	0.02
33	Uranoscopus scaber Linnaeus 1758	-	0.27	-	-
34	Zeus faber Linnaeus 1758	-	0.03	-	-

c) Underwater observations:

During sixteen diurnal censuses a total of 3165 fish were counted. Almost all of them were recorded on the pyramids. The overall trend of the counts (Fig. 5) shows two maxima: spring and autumn, two minima, one very clear at the end of spring and a second in the winter; the latter has so far been studied only on the basis of the one census in February 1989. These seasonal variations are linked to different groupings of species (Figs. 6, 7, 8, 9, 10), of which we highlight the most significant aspects.

The presence of Chromis chromis (Fig. 11) is continuous during the year (cf. Harmelin, 1987 at Port-Cros) with a minimum at the end of the spring. Chromis juveniles (blue in coloration) appear mainly in summer (cf. Spanier et al. 1985).

This species, together with Diplodus vulgaris - a species which is a little more variable from one count to another - forms a large part of the population in all seasons.

Oblada melanura constitutes a substantial percentage of the population in winter and spring; in the other two seasons, however, it disappears.

Blennius rouxi and Coris julis are two summer and autumn species. Of the latter only young individuals were recorded; probably they find a nursery on the artificial reef and subsequently they settle on the Posidonia bed.

The fluctuations in the number of individuals of Diplodus vulgaris and D. sargus (Fig. 12) are due to the habits of these two species. As they are not strictly territorial, they have only a loose connection with the pyramids. Sedentary and territorial species such as Serranus cabrilla and Symphodus sp., on the other hand, show a small variation over the months, except at the moment of recruitment (cf. Bregliano and Ody, 1985), (Fig. 13).

Independence from the substrata is even more marked in Spicara sp., which can be considered a pelagic species (cf. Harmelin, 1987).

The size composition of Spondyliosoma cantharus proves to be of particular interest (Fig. 14). The first samples (Feb, Mar) only registered the presence of juveniles. Later (Jun-Aug) these were replaced by medium-sized individuals. From August onwards adult specimens were also recorded. From October onwards young fish re-appeared. In the last 4 months there was an evident increase in the number of individuals. Apparently, then, in this last cycle of observations we witnessed the conquest of this area by this species. This fact is of particular interest since the adults lay their eggs in nests (Bini, 1968).

The presence of Apogon imberbis was also registered several times from May to October. This fish, which lives in holes and caves of natural rock substrata, could be considered an indicator of the suitability of the reef.

During the nocturnal immersions we have seen how these artificial structures give shelter not only to benthic but also to benthopelagic species, such as Spicara sp.. Nocturnal species, such as Scorpaena sp. appear in greater numbers : therefore the diurnal counts are understimated.

By night we have also noted specimens of Pagellus sp. and of Scyllarus arctus, never seen by day.

Fig.5
Total fish counts in the studied area

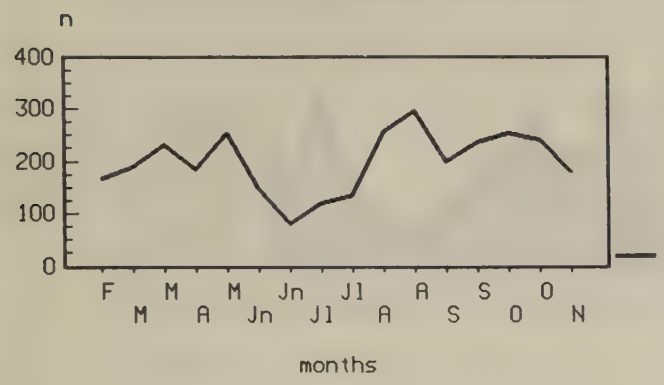


Fig.6
Loano artificial reef
Counts of five main species

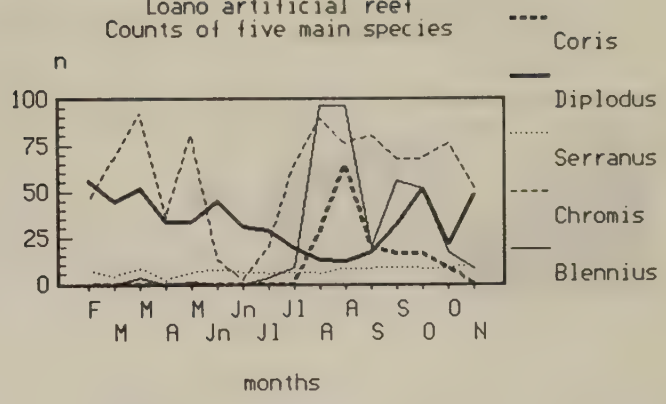


Fig.7
Composition of population
WINTER

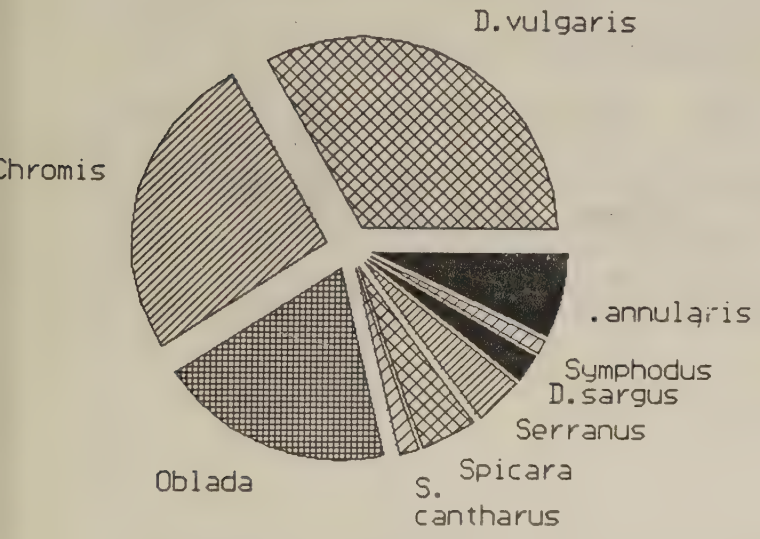


Fig.8
Composition of population
SPRING

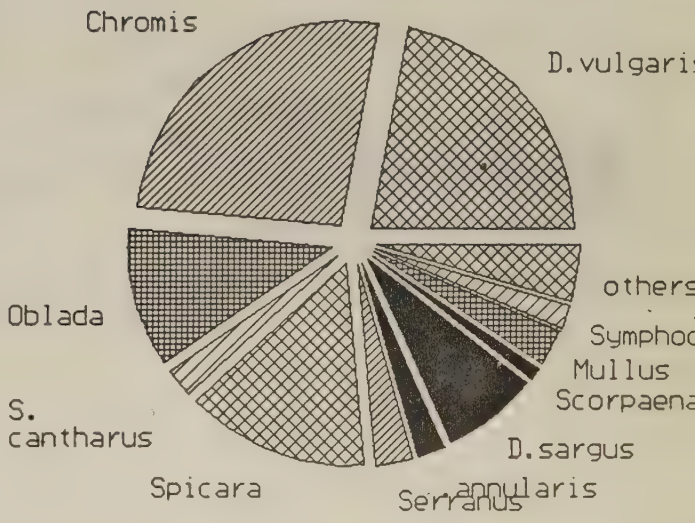


Fig.9
Composition of population
SUMMER

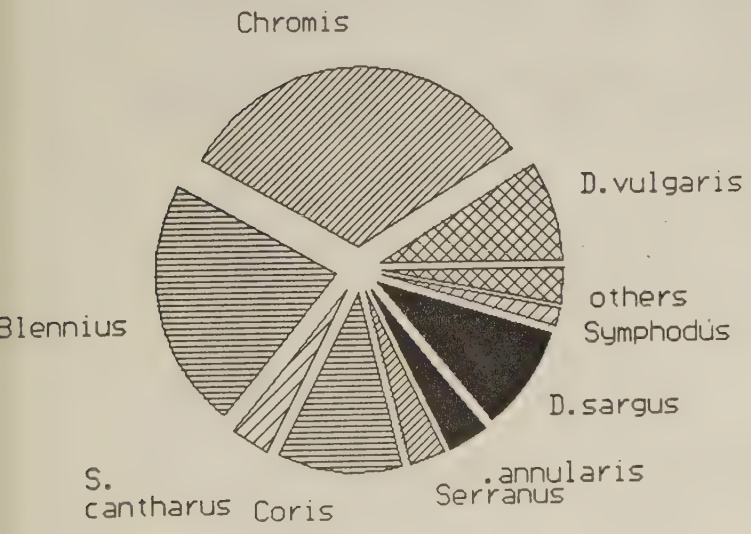


Fig.10
Composition of population
AUTUMN

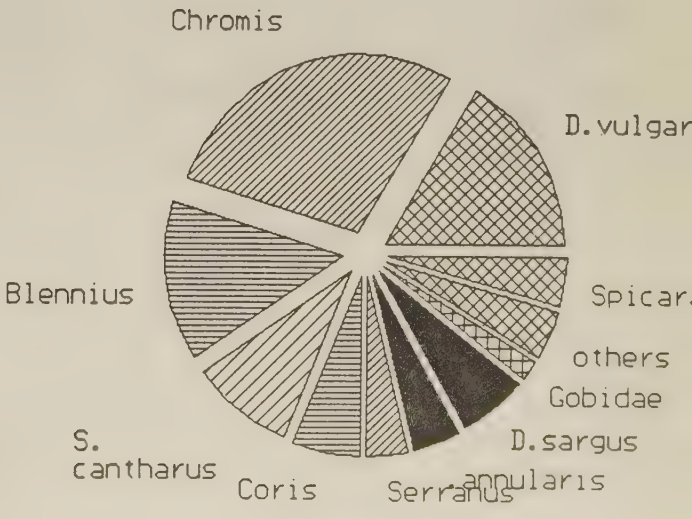


Fig.11
Loano artificial reef
counts of Chromis chromis

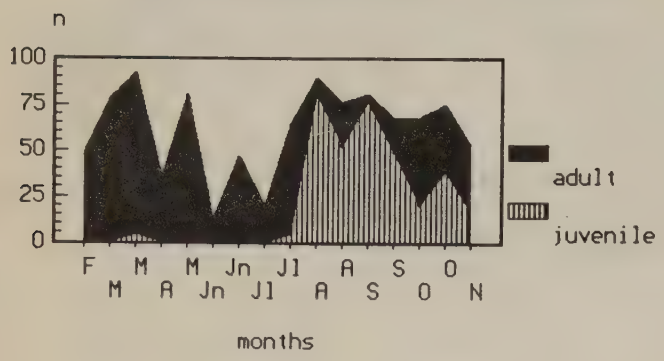


Fig.12
Counts of Diplodus vulgaris

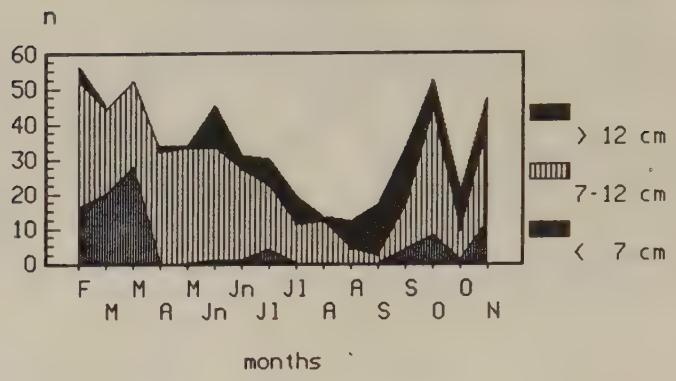


Fig.13
Loano artificial reef
Counts of Serranus cabrilla

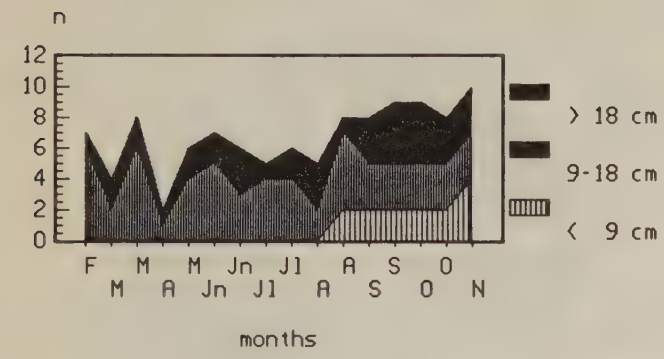
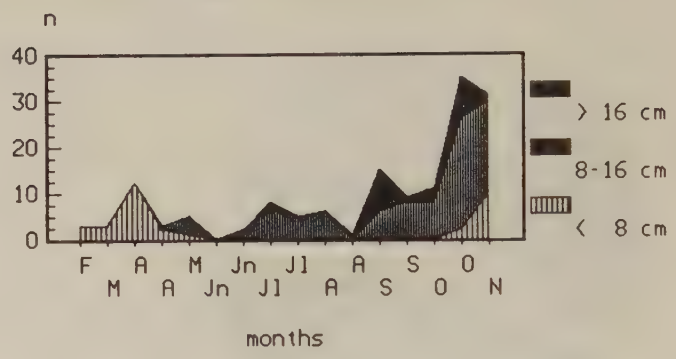


Fig.14
Loano artificial reef
counts of Spondyliosoma cantharus



In conclusion, it can be pointed out that among the species indicated (Table 1), there are some of great interest for fishing and others which are interesting because they document the possibility of re-stocking the bottoms: these are Mycteroperca rubra, Umbrina cirrosa and Sciaena umbra, species which have become rare along the Ligurian coast.

We maintain that the reef has a positive effect and that this could be improved if the fishing ban were successfully enforced.

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A SHORT REVIEW OF ARTIFICIAL REEFS IN SICILY

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KEY WORDS - Artificial reefs, Fisheries, Sicily.

SUMMARY
The construction of artificial reefs in Sicily was first planned as early as in 1974. Peliminary investigations aimed at testing the feasibility of reefs were carried out in the years 1977 - 1981. A detailed description of the benthic communities established on artificial substrata along the coast of Palermo was made. Algal settlements were the commom biotic features on the walls of submerged concrete blocks in full light. Photophobic encrusting associations were dominant in dark hollows and in shady spots. A confirmation of the above model was obtained from bionomic censuses of a small reef set up in 1988 off Terrasini in the Gulf of Castellammare (NW Sicily). Contemporary surveys of artisanal fisheries put into evidence a heavy overexploitation of the biological resources in the coastal area of northern and southern Sicily due to nearshore trawling, water pollution and silting of fishing grounds. Programs for the laying of concrete pyramids were then worked out for the identification of the most suitable coastal sites for reef construction: favorable perspectives exist especially for the northeastern and for the southern sides. Results of fishing surveys in relation to manmade reefs are reported and the role of artificial substrata on yield increment is discussed. Perspectives for a future development of reef technology in the Island are reported.

INTRODUCTION

The ability of artificial reefs to improve fishing yields was probably known in Sicily even before the laying of the first "tsukiiso" and "gyoshio" along the coastal bottoms in Japan (QUERELLOU et al., 1983). According to old fishermen's tales, the piling up of stone ballast used to anchor tuna fish nets and left behind after their weighing has over the centuries, turned the soft sea bottoms off the "tonnare" (tuna fishing ground) into chaotic heaps of boulders. These represented an ideal shelter for white fish such as breams and groupers. Fishing by trammel net and line from late summer to early spring thus followed the tuna catching season in a cyclic exploitation of the marine system.

In other cases, harbour breakwaters and wrecks were places of maximum fishing yields by artisanal methods. This discovery encouraged the sinking of solid waste material to create refuges.

The first artificial reefs in Sicily were laid in the late summer of 1981. On that occasion 4 small pyramids were arranged off Terrasini harbour by underwater assemblage of building material such as concrete pipes and boulders. Since then, two larger reefs have been placed west of Terrasini on the bottom waters of the

Gulf of Castellammare. From the fishermen's viewpoint the outcome from these structures is so far quite positive. From a scientist's point of view, however, many details about the actual processes underlying the enhancement of fish catch are still obscure or even contradictory: far-reaching research is therefore needed before any conclusion can be drawn.

SCIENTIFIC APPROACHES TO MANMADE REEFS IN SICILY: A CHRONOLOGICAL REVIEW

During the past two decades the building up of artificial reefs has been constantly envisaged as a suitable solution to some of the major problems affecting the coastal fisheries in Sicily: i.e. progressive thinning of demersal stocks and decrease of fish size due to:

a. overexploitation of living resources by nearshore trawling;
b. fast-increasing silting as a consequence of misuse of the coastal environment and of the mainland deterioration;
c. losses of potential energy sources in nutrient-enriched waters;
d. other causes due to mismanagement of the enivronment.

Curbing of trawling together with other destructive fishing practices is a major effect brought about by massive rocky outcroppings on an even soft bottom. Posing a severe restraint to trawling was in fact the prime objective of a major reef - system proposed by G. Bombace and reported in a comprehensive plan for the management of the coastal resources issued by the Regional Government in Sicily as early as 1974. A special regional law was then issued with a support of 70 million lire (about US$ 50.000 at the present exchange rate of 1.400 italian lire for one US$) for basic research. However, the law was never enforced nor was the fund ever utilized.

The plan put forward the building up of concrete pyramids in some strategic spots off the island's coast: Gulf of Patti, Gulf of Castellammare, both in the Tyrrhenian; Capo Granìtola and Capo San Marco, in the South (Fig. 1). The model of boulder proposed was based on the one employed in Ancona reefs.

A research project aimed at restocking the Sicilian coasts and at the recovery of the nutrient overloads near urban areas was then carried out from 1976 to 1981 at the University of Palermo in the framework of the National Plan "Oceanography and Marine Bottomns - Biological Resources" promoted by the National Research Council (CNR). The hydrological conditions on some points of the coast around Palermo were first investigated, especially focusing on the nutrient overloads and their recycling through benthic associations. A census of the biotic settlememts living on the surface of breakwaters and other artifacts in semi-enclosed basins was also carried out. The survey facilitated the development of a comprehensive model of the benthic settlements on artificial susbstrata located on the coastal sea floor bottoms of NW Sicily (RIGGIO e ARDIZZONE, 1979; 1981; ARDIZZONE e RIGGIO, 1981; RIGGIO et al., 1982, 1985, 1986). It was the starting point for a feasibility study of artificial reefs in the same areas. At

the end of the study a small artificial reef was built off Terrasini - about 50km west of Palermo - for experimental purposes. Funds of 50 million italian lire (about US$ 35.000 at the present exchange rate) were provided by the Province of Palermo (PROVENZANO e RIGGIO, 1982; RIGGIO e PROVENZANO, 1982). Surveying the biotic settlements of the reef allowed to test the reliability of our model of benthic colonization and its validity over a wide range of environmental conditions (RIGGIO, 1983; RIGGIO et al., 1982; BADALAMENTI et al., 1985). A second reef of much larger size was set up off Trappeto in the Gulf of Castellammare.

Starting in 1982, a comprehensive research project ("Progetto Mare") for the feasibility of artificial reefs was carried out along the coast of the Palermo Province. It gave an insight into the actual perspectives for the reclamation of nearshore bottoms and promotion of artisanal fisheries. Head of the "Progetto Mare" was G. Bombace; S. Riggio and G. Provenzano were co workers in the scientific and technological investigations.

An advanced phase of the project starting in 1985 employed a staff of young biologists with the task of carrying out a survey of the benthic communities and the demersal fish. G. Giaccone joined the research group for the phycological census.

In recent years two agencies have been set up to promote restocking plans (Consorzi di Ripopolamento dei Comuni Costieri) in the Gulfs of Castellammare and Patti. Despite the improvements in artisanal fisheries following reef building, the high costs and the uncertainties about the actual mechanisms underlying fish production suggest the need to collect new data before the laying of new reefs. An unbiased evaluation of the benefits and future perspectives will be attempted in the following sections.

AN OUTLINE OF THE ARTIFICIAL REEFS IN SICILY

Manmade reefs were hitherto built off Terrasini, Trappeto and Alcamo Marina in the Gulf of Castellammre (Fig. 2). No data are available for the reef in the Gulf of Patti. Old cars and other discarded material have also been put on the bottom along the SE coast.

The reefs off Terrasini fishing harbour were assembled at the end of 1981: they consist of 2 pyramids made up of 14 cubic concrete boulders with a 1.4m edge arranged in 3 layers for a comprehensive height of 4.2m. They lie on a sandy bottom at a depth of about -18m (RIGGIO and PROVENZANO, 1982). The biotic settlement shows a dominance of brown algae with Cystoseira compressa being the most represented species. A trend to the establishment of a mature Posidonietum community is evident (BADALAMENTI et al., 1985).

The inner walls of the pyramids are colonized by photophobic associations typical of shady sites such as caves and crevices; i.e., madreporarians, demosponges and bryozoans together with encrusting algae and serpulids. Their common growth makes up an

embedding of tubes and calcareous skeletons on vertical walls. Passive filter feeders such as Spirographis spallanzanii and ostreid bivalves protrude in the tunnels between the boulders. A mature settlement was attained about five years after setting up of pyramids.

A diverse fish fauna lives around the reef: breams and wrasses are particularly frequent. Groupers and crawfish are normal dwellers of the hollows and empty spaces throughout the boulders. Egg capsules of squids and other cephalopods are found hanging from the roofs.

The reef off Trappeto is made of an outer belt of 35 massive cubic boulders scattered around a fishing area about 120 hectares whose shoreside boundary is a gentle rocky slope covered with Posidonia oceanica tufts. The cubic boulders are provided with tough iron hooks; inside the area lie 20 pyramids: 3 of them are assemblages of cylindrical concrete pipes, 14 cubic hollow elements and 3 of both.

A "naif" pyramid obtained by the disorderly piling up of 4 concrete boulders on a basement of stones and pebbles was set up off Balestrate in autumn 1988. The boulders were then covered with discarded materials. It is home to an oyster bed overgrown with encrusting organisms.

Thirty-two pyramids each made up of 14 concrete blocks arranged in 3 layers were built in the years 1986-1988; they were located on a soft bottom ground brtween depths of -5m and -50m between Alcamo Marina and Castellammare del Golfo. Seventy-seven single massive boulders were irregularly scattered in the intervals between the pyramids to prevent trawling. The whole protected area covers about 500 hectares. The waters are subjected to strong currents and the turbidity is intense although to a lesser degree than the waters off Trappeto. Sedimentation rate is high and the plane surfaces of the blocks are carpeted with mud. Due to the instability of the mud-flat and the lack of a stone basement, the pyramids have to some extent sunk into the bottom. A trench has developed around the outer perimeter and the boulders are displaced from their original positions.

Survey of the biotic colonization showed a primary settlement of serpulid polychaetes, encrustant and leafy Bryozoa and ostreid bivalves. These made up most of the biomass in the early phases of development. Ostrea edulis was in fact the most frequent organism on top boulders with large-sized individuals attaining a 12cm diamter and a wet weight of flesh up to 10g. The final settlement was intermediate between those of Terrasini and Trappeto reefs, with a few seaweeds restricted to the most illuminated surfaces and a great host of active and passive filter feeders.

FISHING YIELDS IN RELATION TO THE REEFS

The only quantitative data available are from the survey carried

out in an area off Trappeto, extensively reported in the present volume (see under ARCULEO et al., 1989). A constantly higher harvest was recorded in the protected area: either the number of species or the biomasses increased in comparison to the adjacent unprotected area. Increment ratios were as high as 1.6 to 2.2. Also the mean individual sizes were greater than in samples from the surrounding unsheltered grounds.
Examination from a qualitative point of view showed a large number of "resident" fishes closely related to hard substrata and presumably recruited from the nearby Posidonia oceanica meadows which are not present in the "control" grounds.

The blue damsel fish, the pomacentrid Chromis chromis and the saddled bream, (Oblada melanura), were the earliest colonizers of the small pyramid off Terrasini harbour, attracted to the concrete substrata even during the laying of the boulders.
Numerous wrasses of the Labridae Family followed, together with a few big individuals of the conger eel, Conger conger, which established themselves in the empty spaces between the boulders. Shoals of the sheepshead bream, Puntazzo puntazzo, the two-banded bream, Diplodus annularis, and the white bream, Diplodus vulgaris, were repeatedly observed swimmimg around the blocks. The grouper, Epinephelus guaza and the crawfish, Palinurus elephas, were recruited later. The last immigrant was the cardinal fish, Apogon imberbis acting as sentries before the darker hollows. It was considered an indicator of reef maturity.
The bass, Dicentrarchus labrax, the grouper, Epinephelus guaza the red mullet, Mullus surmuletus, and swarms of non resident fish were soon observed swimming near the blocks.

Pelagic species were the most abundant catch at the reefs off Castellammare. The amber jack, Seriola dumerilii, and the bronze bream, Pagellus acarne, were harvested in large numbers from the very laying of the boulders. As much as 1.400 kg of the trigger fish, Balistes carolinensis, were also harvested in only one day soon after installation of the reefs. Other fish species commonly collected in the same area were the Pandora, Pagellus erythrinus, the common sea bream, Sparus pagrus, and the annular bream, Diplodus annularis. Among the last immigrants were some gadids, groupers and young individuals of the spiny lobster, Palinurus elephas.

DISCUSSION OF THE RESULTS
Two major features should be distinguished in the evaluation of the effects of a reef:
a. the possible benefit to professional fishermen resulting from improved fishing yields;
b. the gain of scientific information related to the benthic settlements on the artifical substrata.

Fishing profitability of the reefs built hitherto seems to be undisputable; improvement in the yields has in fact been recorded even in silted or partly collapsed reefs as in those off Alcamo Marina. "Fishability" is especially affected because of the attraction and concentration of fish populations around the solid

substrata. Such an influence is to some extent enhanced with increasing reef size, but also the reef location plays a role: the largest catches of pelagic fish were in fact reported from the massive pyramids off Castellammare; catch of "non-resident fish" has been proportionately lower around the small pyramids at the two other sites.

From a bionomic point of view, the reefs have been reliable indicators of water quality as well as of the biotic potentialities of the marine environment.

A point enlightened by our research is the substantial difference of the benthic colonization of our reefs from that taking place in other known Mediterranean sites (DEBERNARDI, 1980; ARDIZZONE and CHIMENZ, 1982): it is consistent with the sudden change of biogeographical factors occurring in the southern Tyrrhenian (RIGGIO e ARDIZZONE, 1979; 1981). Another point is the perfect agreement with the pattern of ecological succession outlined for subtropical waters (CHANG, 1985). Both points are well illustrated by the differences in the biotic settlements occurring in the 3 reefs under examination: the rather healthy hydrological conditions enjoyed by the pyramids off Terrasini are reflected in the luxuriant algal growth and in the number of demosponges and encrusting organisms. The worsening of water quality results in the elimination of the alga and selective development of filter feeders at the restocking area off Trappeto.

A slow recovery of water quality seemingly takes place in the outer reefs off Alcamo Marina. Only in this last case are the bivalves effective colonizers.

CONCLUSIONS AND PERSPECTIVES

Artificial reefs serve a variety of purposes ranging from prevention of trawling and creation of refuges for fish, to reclamation of endangered bottom grounds. The final goal of such objectives is a policy for a non-destructive management of the coastal biota and of its renewable resources: if properly laid and used, manmade reefs are a valuable tool.

Because of its long ranging coastal perimeter, of the relevant role of regional fisheries and of the heavy overfishing, the interest in Sicily in the availability of such an instrument is great. A compelling demand comes from artisanal fishermen for mechanical deterrents to trawling and secondarily for fish refuges. Highly favourable conditions for reef laying are present in relation to:

a. presence of artisanal fishing communities;
b. suitability of bottom grounds for the installation of massive hard substrata.

The first condition is met with mainly in larger bays - as in the Gulfs of Palermo, Castellammare, Patti (all situated on the northern coast) and Catania (in the East) - as well as on steep

high coastline in other parts in the NW and in the East of the Island.

The second condition is typical of soft grounds and especially of gently sloping bottom plains. Soft substrata stretch off the Tyrrhenian coast east of Palermo where they are restricted to a narrow littoral stripe; the southern coast where they constitute a continuous platform stretching an average of 3 miles offshore prior to attaining a depth of -50m (in some spots however a 50m depth is attained as far offshore as 7 miles).

Either the bottoms of the bays or the soft littoral grounds are subjected to heavy nearshore trawling which accounts for most of the overfishing and destruction of the nurseries. The abuse of illegal fishing gear and poisoning of underwater refuges also cause considerable damage. High silting rates due to intense erosion of the coastline and water pollution, add to environmental disturbance. Laying of artificial reefs is just one of the means of allowing Sicilian fisheries to recover from overexploitation; other means in addition are of course necessary to ensure a satisfactory reclamation of the coastal systems.

One can therefore identify the more suitable environments for the installation of artificial reefs in Sicily (Fig. 2):
(a) in the major bays;
(b) along the NE coast;
(c) in the sand- and mud-flats stretching off the southern coast
The remaining NW and NE coastal grounds are rather unsuitable due to their rocky nature or occupation by continuous Posidonia oceanica beds, as in the W or in the SE: in such a case extensive artificial reef systems would be of a lesser use or even dangerous to seagrass meadows. Some perspectives do however exist for the assembling of small-sized pyramids aimed at protecting restricted nursery areas or even at recovery of endangered Posidonia beds.

After the scattered undertakings of recent years a comprehensive plan for reef-building in Sicily is needed; the possibility is ensured by a law recently made by the regional government for fishery improvement. Such a plan should take into account the greatest possible number of the features relevant to such a complex matter, promoting all the necessary ecological and technological research. Arguments such as the presence and organization of fishing communities should also be examined and the perspectives for a gradual increase of an open-sea mariculture carefully evaluated.

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Fig.1 - Sites of reef location according to 1974 planning

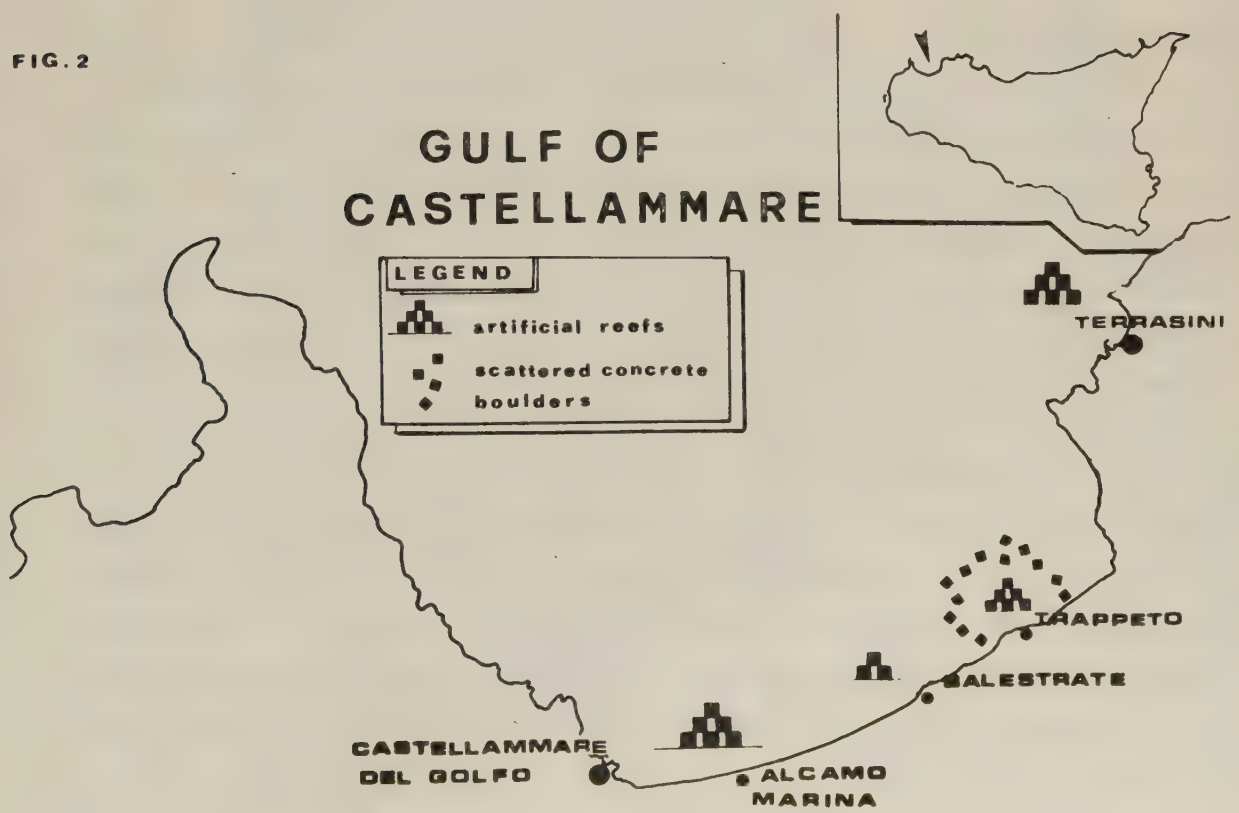

Fig.2 - Arrangement of artificial reefs in the Gulf of Castellammare

ZOOBENTHIC COLONIZATION OF A SMALL ARTIFICIAL REEF IN THE SOUTHERN TYRRHENIAN SEA: RESULTS OF A THREE-YEAR SURVEY

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KEYWORDS: artificial reefs, zoobenthos, Mediterranean, Sicily.

SUMMARY

Polychaeta, Gastropod Mollusca and Polyzoa form the bulk of the settlements on the artificial reef under study. An increase in the number of species and in the percentage cover is evident throughout the ecological succession taking place on the concrete boulders. Animal taxa are in close relation to the algal settlements. Complex food webs develop in the course of the colonization and support an even larger number of carnivores and detritivores.

INTRODUCTION

Tha benthic colonization of the small artificial reef off Terrasini in NW Sicily has been investigated since the laying of the reef in October 1981. Sequential examination of the biotic settlements has allowed us to sketch a picture of the succession of benthic communities (**RIGGIO, 1982; RIGGIO et al., 1985; BADALAMENTI et al., 1985**) which is only partly consistent with the behaviour exhibited by similar structures set up in other coastal sites of the Mediterranean Basin. Although a recruitment of fish and cephalopods in the area is evident, close estimates of the fish fauna may be of little value due to the small size of the reef. The relations of fish with the benthos growing on the two truncated pyramids are also unclear. This uncertainty, in our opinionn, is not due to a lack of investigation, but rather to the non-linear processes of benthos development taking place on the reef and which are ultimately a consequence of the higher diversity and the low primary productivity typical of a subtropical marine environment as in fact the lower Tyrrhenian Sea is. Our present contribution is therefore merely a starting point for new more sophisticated research on the trophic and biological networks developing inside and in close proximity of the reef.

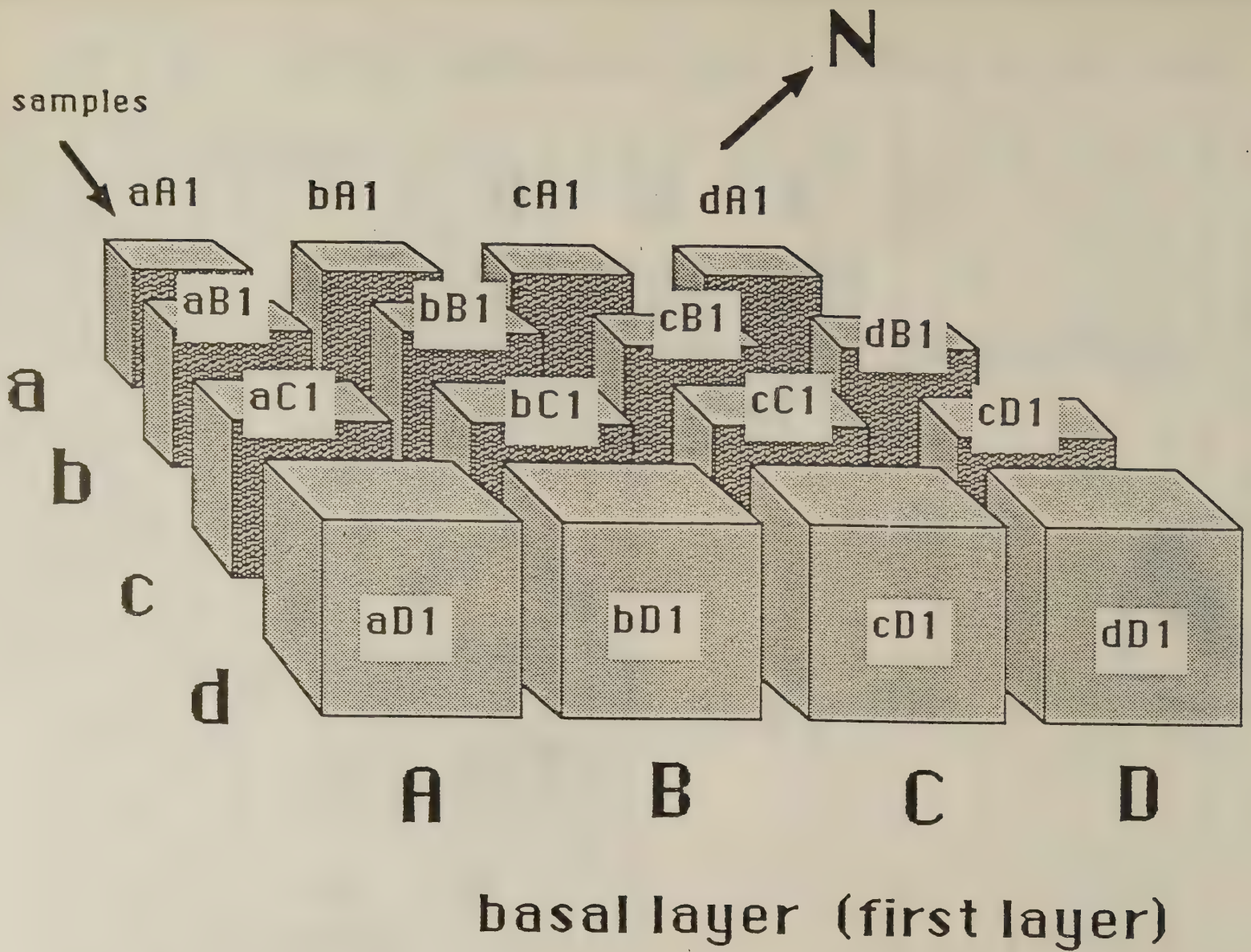


Fig. 1, a - Basal layer of cubic boulders in the reef.

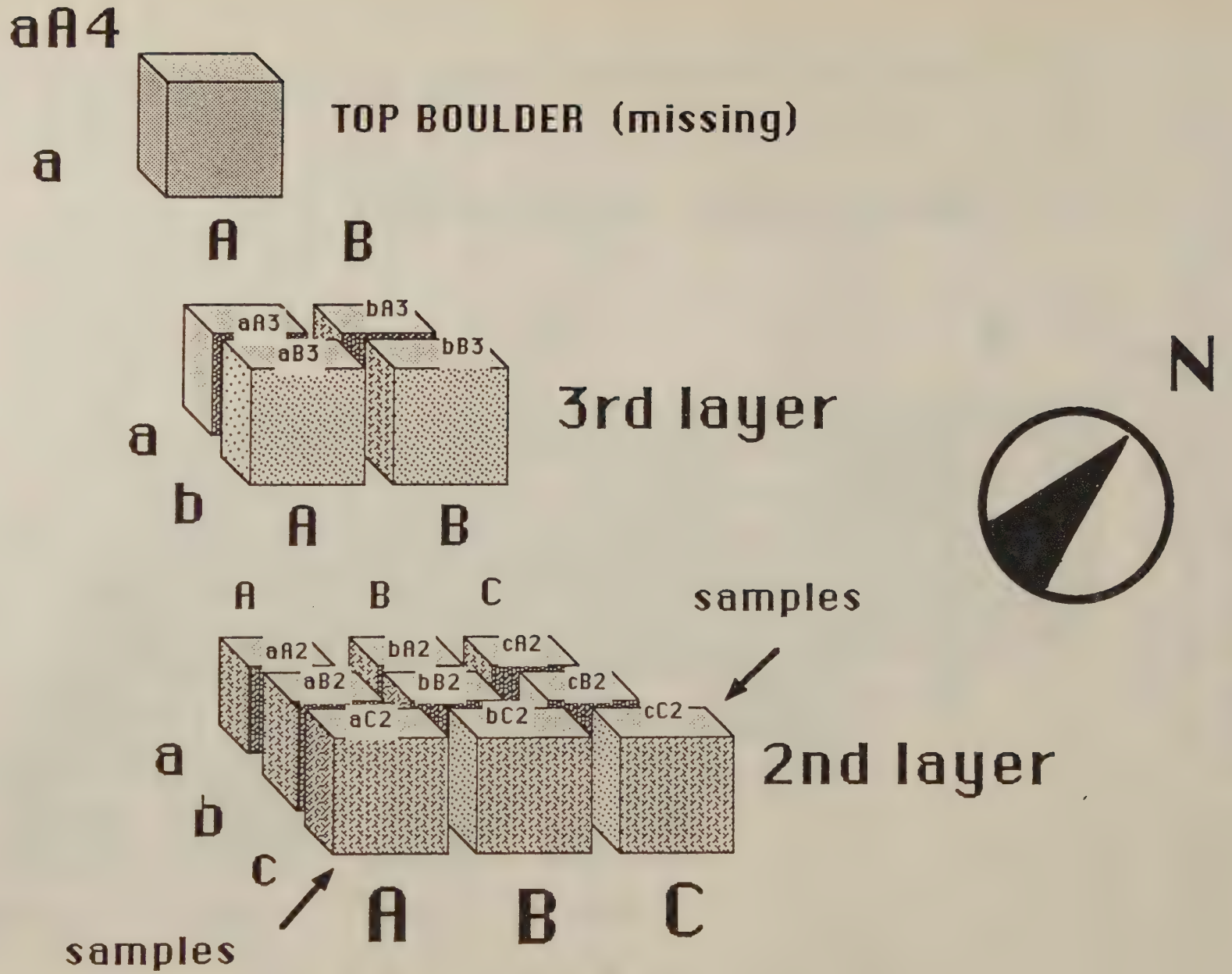


Fig 1, b - Upper layers of cubic boulders in the reef

METHODS

The procedures employed are extensively dealt with in previous contributions (**RIGGIO et al., 1985; BADALAMENTI et al., 1985**). They may be summarized as follows: samplings were carried out by **SCUBA** divers about **6, 10, 20, 32** and **36 months** after the establisment of the reef. Standard **400cmsq** areas were removed from the centre of the **4** exposed walls of the outer boulders. Three boulders from the ground level, **2** from the **1st** level and **1** from the top were examined (**RIGGIO et al., 1985**). Boulders **aA1, aA3, cC2** and **aC2 (Fig. 1, a and b)** were sampled more than once, so that the final number of samplings was **10,** with a total number of samples of **40.** The concrete cubes examined in **August 1984** and in **October 1984** were, respectively, **aA3** and **cC2**. Samples were obtained from the interior of the reef or from the tunnels crossing the blocks, since the access to divers was impossible. Algae and debris were washed in seawater and sieved to a mesh size of about **0.5mm**. Handsorting was carried out using a stereolens; individuals and colonies were counted and taxonomically identified. To make our procedure consistent with the one currently used in bionomic research, colonial densities were expressed as percent cover. Also the densities of individual taxa were expressed as **% cover**, multiplying the numbers by suitable conversion factors. To simplify the calculations, percentage coefficients from **0.1 to 0.9** were employed according to the size of the species.The algae and some minor invertebrate groups were isolated and are still under examination.

RESULTS

A constant increase in the number of species as well as in the percent cover or in the diversity is evident if the pyramid is considered as a whole system; i.e. if average values for each boulder or for a group of boulders are taken into account (**Fig. 2a, b**). Discrete values result instead when single cubes are separately examined, which seemingly contradict the trend shown by the whole structure (**Fig. 3**). The values are more similar if cubes and/or walls showing the same orientation are compared. A very similar behaviour is apparent for the horizontal faces on top of the cubes (**Figs. 4 and 5**).

The overall rise is very steep in the early stages; i.e. within **2 years** after the onset of colonization whereas a decline in the increase with a tendency to an asymptotic growth of all values is evident in the samplings from **24 to 36 months**.

The numbers describing the development and their relative percentages are about **40 taxa** in the **6 months** after submergence, with a lower value - **35** taxa- in the basal block at the **1st level.** The above numbers redouble **6 months** later, to attain about **90** after **2 years,** with a maximum close to **100** and a minimum at **85.** Three years after submergence, the numbers approach **100 per cube** with small differences betwen the

Yearly average numbers of species during the settlement.

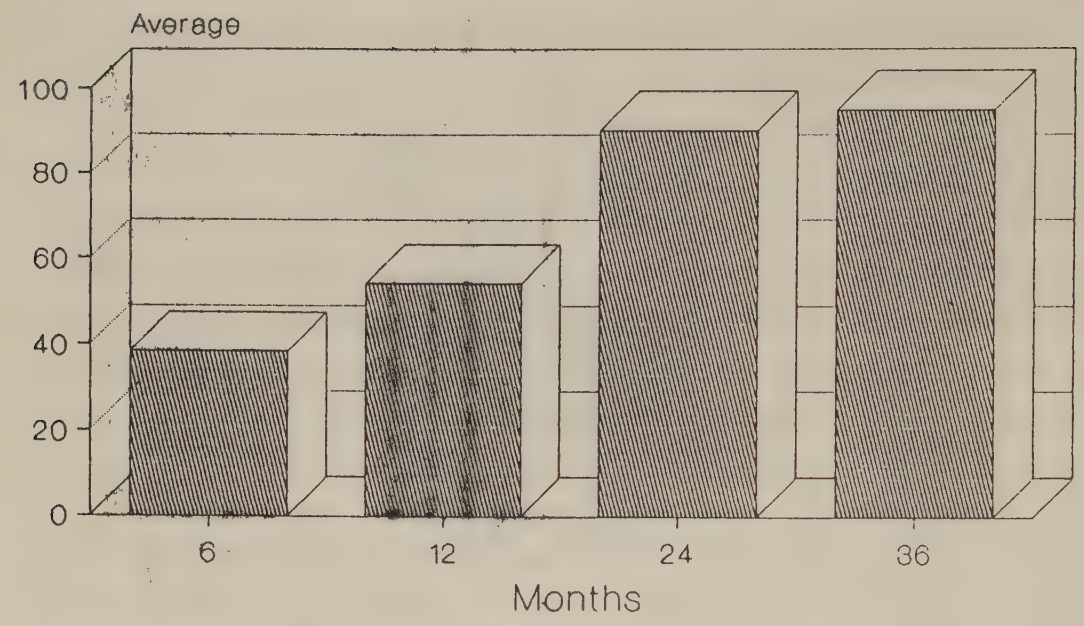


Fig. 2a

Mean diversity H index per boulder during the settlement.

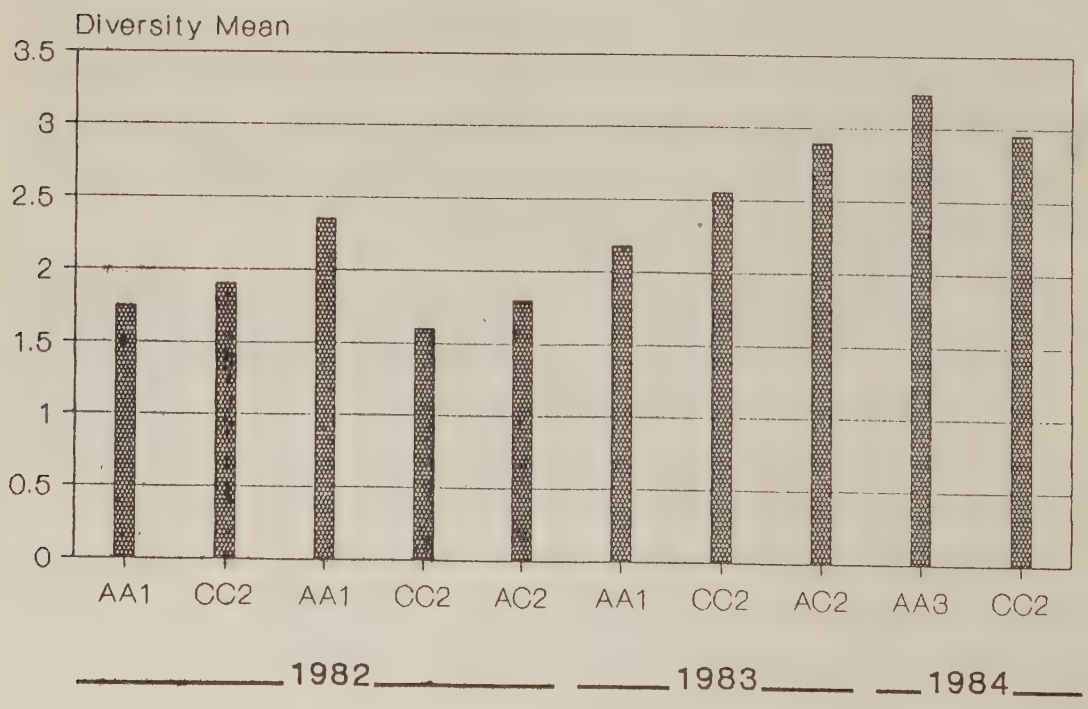


Fig. 2b

Total number of species per boulder during the phases of settlement.

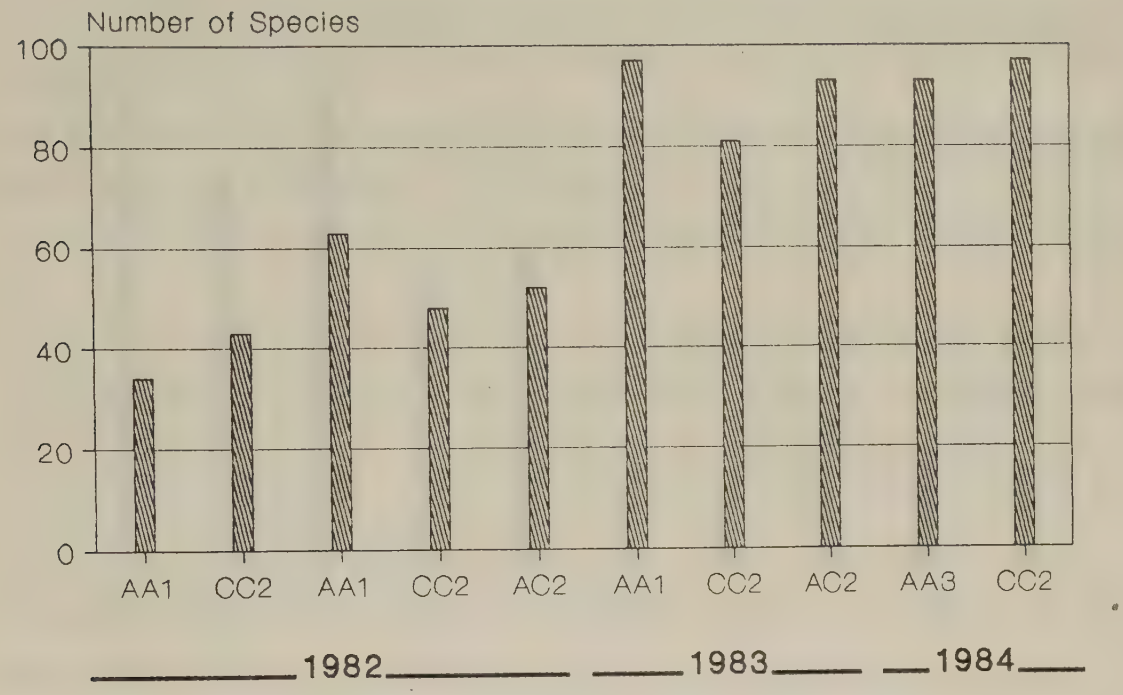


Fig. 3

Percent cover on the horizontal surfaces of the cubes

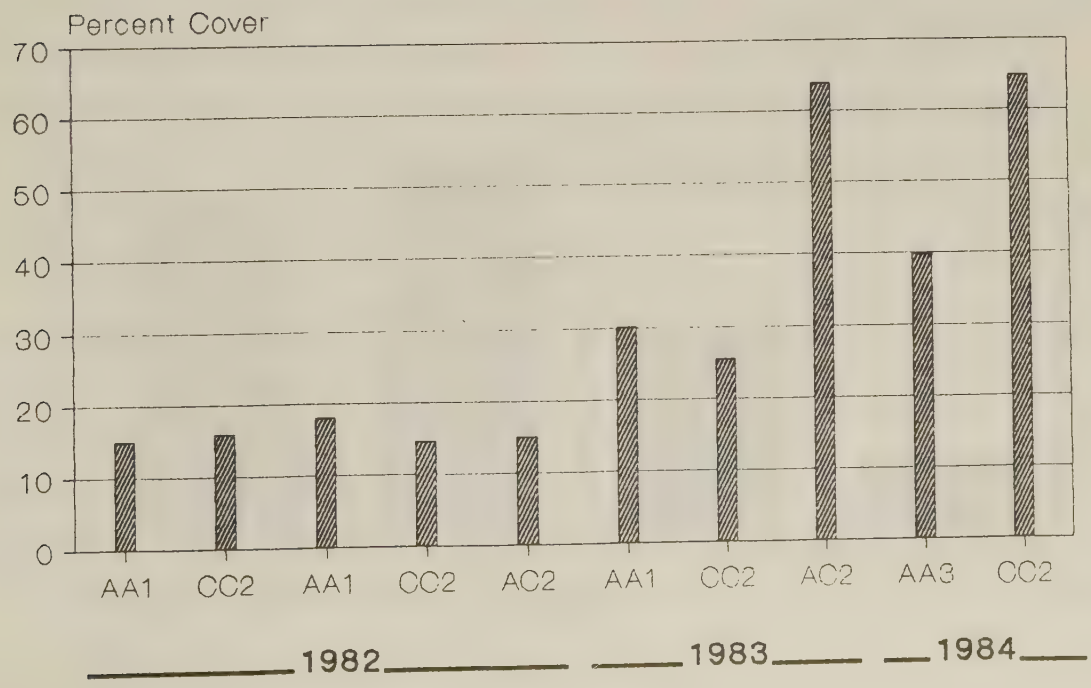


Fig. 4

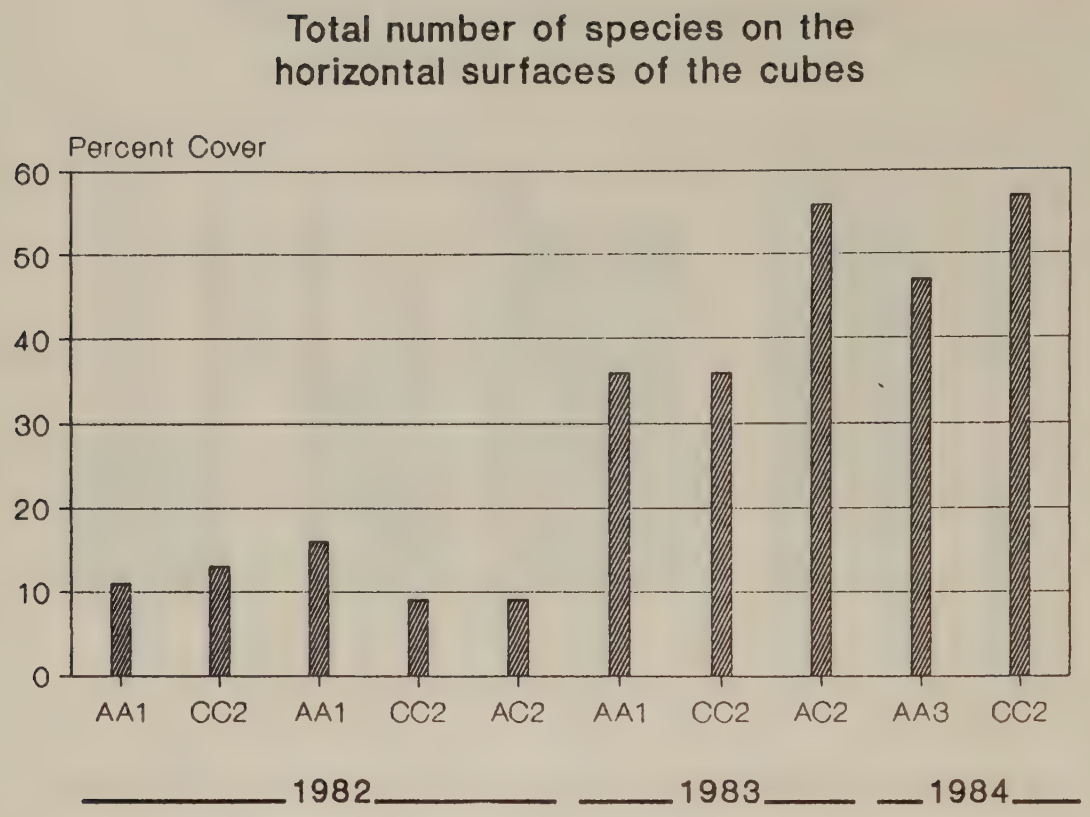

Total number of species on the horizontal surfaces of the cubes
Percent Cover
60
50
40
30
20
10
0
AA1
CC2
AA1
CC2
AC2
AA1
CC2
AC2
AA3
CC2
1982
1983
1984

Fig. 5

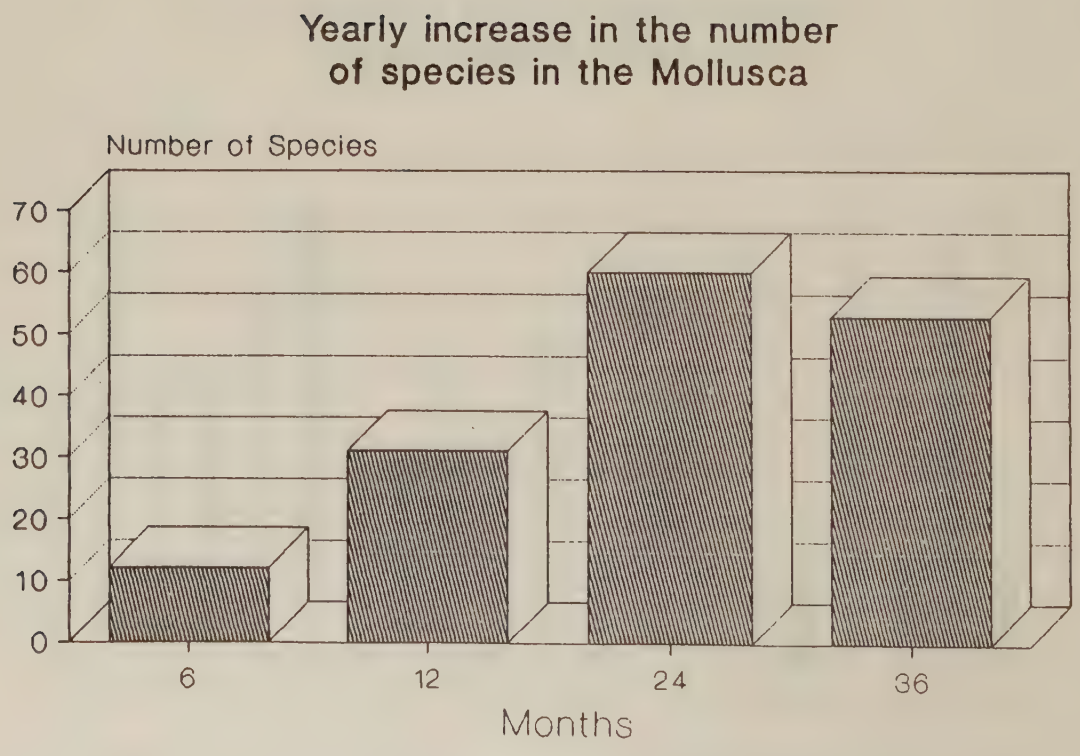

Yearly increase in the number of species in the Mollusca
Number of Species
70
60
50
40
30
20
10
0
6
12
24
36
Months

Fig. 6a

samples. Summing up the numbers of species included in the most represented groups of the **Poluychaete Annelida,** the **Mollusca** and the **Polyzoa (Fig. 6a, b)**, one finds an increase from **155 to 247** in the **16-18month** period between **spring 1983 and summer 1984.**

The **Mollusca** are massive immigrants after the **2nd year** when their number shifts from **46 to 60,** with a **22%** increase. The **Bivalvia** are quite absent in the first stages but show a limited recruitment starting from the **2nd year** following the establishment of the reef.

As stated above, the taxonomic constitution of the settlements shows a sharp dominance of the polychaete **Annelida,** of the **Gastropoda** and the **Bryozoa.** Other groups, such as the **Porifera,** the **Crustacea** and the **Bivalvia** are a negligible component in the early phases but tend to increase from the **3rd year** onwards. Some remarks follow as to the qualitative changes occurring in the course of the colonization.

POLYCHAETA - The dynamics of colonization show in the early phases a massive invasion by serpulids represented by as many species as **12;** they decline to merely **4 one year** later. An increase both in number of species and of population densities in the **3rd** year occurs in the following groups: **Aphroditidae, Phyllodocidae, Syllidae, Lumbrinereidae, Sabellidae** and other minor representatives.

Other groups, such as the **Nereidae,** the **Eunicinae,** and **Terebellidae** are rather stable and include widely distributed forms with herbivorous or detritivorous habits, such as *Platynereis dumerilii*, *Eunice vittata Lysidice ninetta* and *Nematonereis unicornis*. The changes observed in the taxonomic composition also imply a major transformation of the trophic structure occurring in the course of succession with an ultimate tendency to dominance by carnivores and deposit feeders (**Fig. 7**). Other features in the taxonomic constitution can be outlined as follows:

there were **7** species of **Aphroditidae, 5** of which were collected in **August 1984** from the top boulder, **aA3.** The **Phyllodocidae** appeared with **11** species from the **2nd** year onward and were mainly found in **aA3.** The Syllidae were represented in the first 2 years by as few as **10** species - all **Syllinae** and **Exogoninae**; the last 2 samples showed the addition of **24** species, mostly **Eusyllinae** and **Autolithinae**. The late stages were also characterized by a massive encroachment of the opheliid *Polyophthalmus pictus* and by the sabellid *Amphiglena mediterranea* Leyd. *Sabellaria spinulosa* also made its first appearance.

MOLLUSCA - Early molluscan settlement was restricted to the **Gastropoda.** The **Bivalvia** were found one year after the establishment of the reef, and were represented by a tiny number of species which showed a small increase in the following years (**Fig. 8**).

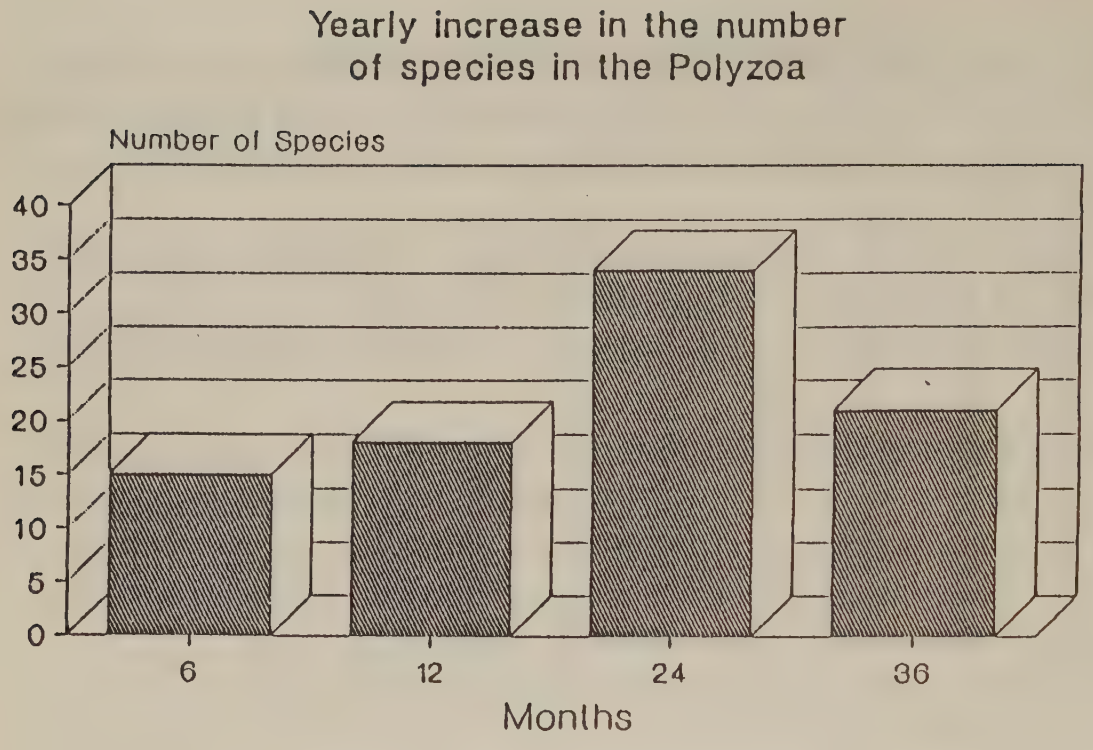
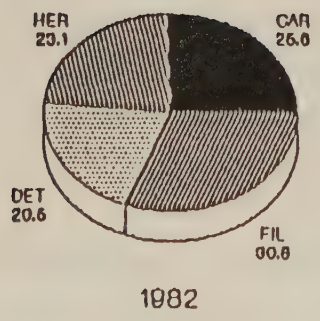
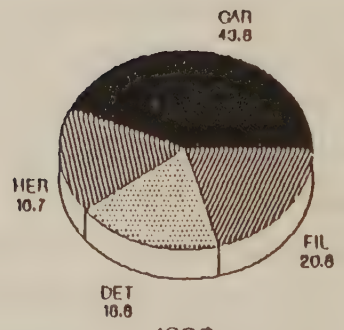
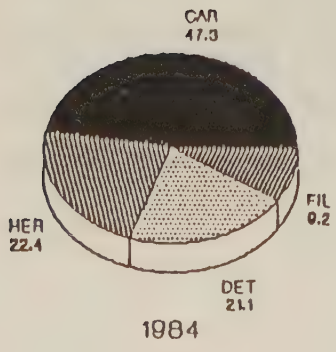


Fig. 6b

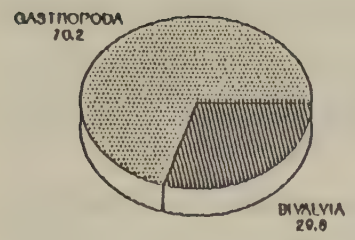




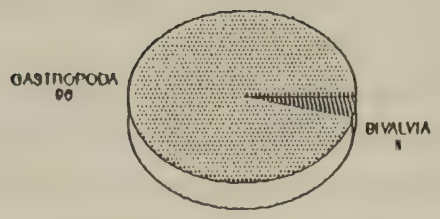


Spectra of the trophic groups in the Polychaeta during the settlement (in percent).
CAR = Carnivores;
HER = Herbivores;
FIL = Filter feeders;
DET = Detritivores.

Fig. 7



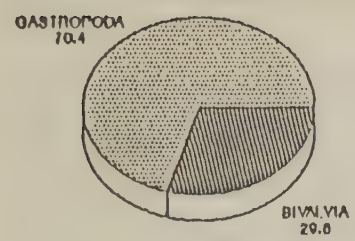
1982



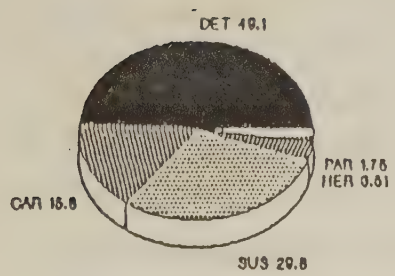
1983

Gastropoda/Bivalvia ratio
(Number of Species)

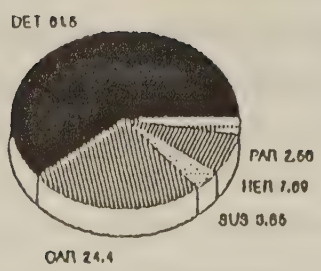
Fig. 8



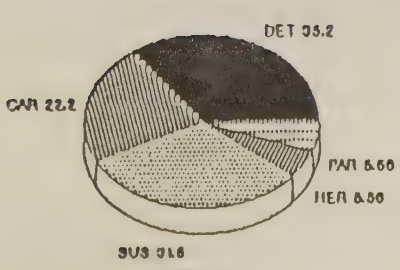
1984



1982



1983



1984

Spectra of the trophic groups
in the Molluscs during
the settlement (in percent).
CAR = Carnivores;
HER = Herbivores;
SUS = Suspensivores;
DET = Detritivores;
PAR = Parasites.

Fig. 9

The first **Gastropoda** were very common ubiquitous taxa, mostly **Rissoacea.** After 6 months a few scattered individuals of *Bittium latreillii* were found. The populations of this species grew to attain an absolute dominance over one **year** either from a numerical or from a biomass point of view. *B. jadertinum* was a late settler and, together with the congeneric *B. latreillii*, it gave rise to mixed populations.

Maxima in the presence of the **Rissoidae** were recorded in **summer 1984,** in coincidence with the highest development of the algal cover. Analysis of the feeding habits shows a steady dominance of the detrititvorous taxa; the carnivores however increase their presence, although at a lower rate. Also, suspensivores and herbivores show an increase **(Fig. 9).** Two typical scavengers - *Hinia incrassata* and *Nassarius cuvieri* - were recorded in the latest sample, while *Triphora perversa* L. and *Cerithiopsis tubercularis* are known as predators of demosponges **(BOUCHET, 1984; FRETTER AND GRAHAM, 1982).**

The first **Bivalvia** were the ubiquitous *Musculus costulatus, Petricola lithophaga* and *Hiatella arctica.* This one is a typical dweller of small crevices in rocky habitats. The bivalve populations steadily develop throughout the **2nd year,** exhibiting an increase related to a tendency toward the making up of typically encrusting complexes. Outstanding representatives of reef builders in shady rocky habitats are in fact the oyster-like scallop *Spondylus gaederopus,* the Mediterranean jewelbox *Pseudochama gryphina,* the ark shell *Arca noae* and the file shell *Lima lima.*

Young *Mytilaster minimus*, a typically representative taxon related to the infralittoral fringe, are commonly found throughout the colonization, although in low numbers.

POLYZOA - Pioneer taxa expanding over the bare walls of the cubes are typically encrusting forms, whereas the ones thriving inside the holes and in the shady walls are especially bushy colonies like *Caberea boryi* and other taxa showing similar habits. The appearance of the **Aeteidae** is consistent with the layering of debris and detritic particles on the horizontal platforms or within calcareous volumes.

At the latest stages a massive recruitment of both **Aeteidae** and **Cyclostomata** occurs as a consequence either of luxuriant algal vegetation supporting many epiphytic species, such as *M. lepralioides* and *S. sanguinea,* which live on the thallus or within the leaflets of the brown alga *Halopteris filicina.*

MINOR GROUPS - Within these may be included the **Porifera** and the **Crustacea.** It is worth mentioning the almost complete absence of the **Echinodermata** (with the exception of some small **Holothuroidea**) and the occasional appearance of Tunicate colonies.

The **PORIFERA** are mainly **Calcispongiae** of the genus *Sycon;* in the last year however a thick carpet of **demospongiae**, mostly *Cacospongia* sp., occupies the spaces surrounding the algal tufts.

The **CRUSTACEA** are present with the **Peracarida** and **Decapoda. Amphipoda** and **Tanaidacea** appear in the early stages; the **Tanaidacea** then decrease; on the contrary the **Amphipod** populations grow markedly attaining densities as high as about **300** individuals per cube which almost redouble in the most recent samplings.

The **DECAPODA** are few at the beginning, mainly restricted to **Paguroidea** occupying the empty shells of *Bittium* and young *Pisa* spp. A tendency to increase in numbers is also evident. The increasing presence of small **Natantia** and of juveniles of *Palinurus vulgaris* inhabiting the holes on the wall surfaces is also well documented.

DISCUSSION

Information gathered from our previous surveys (**RIGGIO, 1982; RIGGIO et al, 1985; BADALAMENTI et al., ,1985**) stressed the significance of the colonization phases in the assessment of the effciency of an artificial reef in providing refuge and food for fish. Both aspects of our problem, i.e. the ability of the biotic complexes growing on a hard substratum to attain a mature stage and their capacity to convert potential energy into a useful form, seem to be strictly related. The interest in a more thorough knowledge of the ecosystem of our concrete pyramid is further enhanced since we have taken the reef off Terrasini as a model of the behaviour of similar structures in the southern Mediterranean, provided that they are established in clear waters.

A true ecological succession indeed occurs on our reef, which is totally different from the abrupt invasion of the substrata by filter feeders occurring in the Adriatic (**BOMBACE, 1980, 1982**) or in the mid Tyrrhenian (**ARDIZZONE et al., 1982**). Analogies exist with settlements reported from off the southern French coast (**DUVAL et CANTERA, 1983**) and the Ligurian Sea (**BALDUZZI et al., 1982; RELINI, 1982**). The hitherto observed processes are part of a true ecological succession, which tends to a mature stage dominated by the ***Cystoseiretalia*** in the faces most exposed to light (**BADALAMENTI et al., cit.**).

The different orientation and exposition of each face to light and currents markedly affect the patterns of succession. If one refers to the simplest pattern of community development, taking place on the upright outer walls facing the open sea, the succession can be defined as a discontinuous phenomenon proceeding by major steps (**RIGGIO e ARDIZZONE, 1979**); i.e.;

A - encrusting blade-like organisms together with small felt-like algae and films of microorganisms;

B - growth of small algae (e.g. *Halopteris filicina,* and other brown algae) and branching colonies of filter feeders;
C - settlement by large algae (*Cystoseira* and *Sargassum* spp.) and establishment of a persistent long-living algal cover.

The colonization by invertebrates is strictly bound to the algal growth, and in fact every new species recruitment coincides with the settlement of new algae. Such a phenomenon has become evident from examination of the **3-year** samples which showed the addition of a numerous diversified fauna typically associated with *Cystoseira* spp. or with other brown algae **(PERES et PICARD, 1964; BELLAN-SANTINI, 1969).**
The population outbreaks of *Polyophthalmus pictus* and *Amphiglena mediterranea,* or of the numerous **Rissoidae,** as well as of the whole caprellid group, may be assumed as being directly related to the luxuriant growth of *C. compressa.*
The horizontal faces behave differently because of the higher silting which is responsible for the creation of a thick carpet of soft sediments suitable to species living in detritus or in sand such as **aeteid Polyzoa, eunicid Polychaeta** and **Gastropods** like *Bittium* spp. Colonization of horizontal faces seems to tend rather to a **Posidonietum** as a final stage of succession, and the finding of some juvenile *Pinna nobilis* should be a confirmation of such an assumption.
The faces in the shade, such as those inside the reef, are colonized by typical photophobic taxa with calcareous skeletons giving rise to heavy encrustations; therefore the development of a **"précoralligène"**
stable settlement should be expected, without much chance of a progress to a true **coralligéne (PERES and PICARD, 1964)** owing to the high silting rates. Only the innermost walls show the presence of madreporarian and of extensive sponge colonies which should be interpreted as pertaining to a **"cave comunity".**
Erect encrusting forms protrude from the walls of the tunnels connecting the opposite faces of each boulder. Their growth is very intense, very likely favoured by the steady water inflow.
The low density of some indicators of the mature stages, such as the demosponges (which are at their early onset) means that the process of succession is still going on and it is very likely to take from **3 to 5 years** to attain its maximum stability, as observed on the submerged breakwaters of nearby harbours **(RIGGIO e ARDIZZONE, 1979; 1980).** The high frequency of the juvenile classes and the lack of adult and large-sized

individuals, particularly in the groups living on soft bottoms, proves that the reef systems is still at an immature stage. The cube pyramid can be thought of as an effective nursery for invertebrate populations which could be fed upon intensively by small predators or even migrate back to the surrounding sandy grounds. Changes of community composition are also reflected in the changes of feeding habits shown by the leading groups of the **Polychaeta** and of the **Gastropoda,** where a marked increase of the carnivores and of detritus feeders is evident.

Contrary to what is known from the literature, the filter feeders are a minor component, which is quite irrelevant at the very early stages. A role might be played by the sponges which are fed upon by specialized gastropods which are ultimately seized by carnivorous fish. The role of the Bivalvia is very low since they are but a small fraction of the **Mollusca** and a tiny fraction of the total.

This is, in our opinion, what mostly distinguishes our reef from the reefs in mid-Tyrrhenian **(ARDIZZONE et al., 1982)** and in the Adriatic **(BOMBACE, 1980, 1982),** and mostly affects its efficiency in the restocking of the area. The low number of filter feeders involves a low rate in the conversion of seston to potential prey for fish, and therefore a low ability of the reef to "produce" fish. This is however what happens on natural rocky substrata of northern Sicily, which are blanketed with seaweeds even in eutrophic conditions but do not show any appreciable mussel- or oyster- settlement.

Only in situations of very serious domestric and industrial pollution, as the one affecting the Gulf of Castellammare **(D'ANNA et al., 1985)** and in a few other places are *Mytilus galloprovincialis* able to thrive and reach an appreciable size.

In "normal", up to eutrophic conditions, only *Mytilaster minimus* Poli is likely to be found. The typical yields of our coastal fishery are therefore bound to the outcome of complex food webs based on the productivity of benthic algae, and this results in a powerful constraint to the attainment of high fishing yields. In this respect, our reef behaves mostly like the nearby natural rocks, and its probable low productivity should be related to the low primary productivity of our coastal waters. From preliminary surveys we have found that the most prized fish caught by artisanal fishery feed primarily on benthic **Decapoda** (small prawns, **Galatheid** shrimps), **amphipods** and **polychaete** worms. The Decapoda seem to be not very common in the reef (but their apparent rarity could also be a bias of censusing consequent to collecting methods unsuitable for the sampling of motile forms), but they are rather frequent in the nearby seagrass beds, and therefore it is very likely that the reef might be a refuge in the day for fish which migrate to richer pastures in the surrounding seagrass beds at night, as observed by **RUSSELL (1975)** in New Zealand. The rise of **Amphipod** populations, which are a normal food item of many fish, is a favourable perspective for the development of an exploitable food web.

CONCLUSIONS

The small experimental reef laid off Terrasini offers a strong argument in favour of the high diversification of the marine biota in the southern Mediterranean. The artificial reef under study may be assumed to be a natural rocky habitat showing a pattern of ecological succession in which the algae and the encrusting forms are dominant. Recruitment occurs mainly from the brown alga community, but also the **Posidonia** beds and the photophobic encrusting biocoenoses largely contribute to the settlements. Saturation of niches goes on rather slowly and high diversities are likely to be attained, so that this phenomenon seems to affect negatively the biological productivity. As a consequence, the ability of the reef to recycle energy into a useful form is thus slowed down, but this is a characteristic common to almost the whole rocky habitat in the southern and perhaps even in the northern Mediterranean, although to a lesser degree.

From a purely theoretical point of view, they are also an invaluable means of investigating the marine environment and throwing light on the many intriguing problems related to the management of the coastal environment and the sound use of the resources.

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PRELIMINARY DATA ON AN EXPERIMENTAL TRAMMEL NET SURVEY DESIGNED TO ESTIMATE THE POTENTIAL OF A PLANNED ARTIFICIAL REEF NEAR MAZARA DEL VALLO (ITALY).

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INTRODUCTION

The problem of the rational exploitation of coastal resources is increasingly in the public eye, both in the scientific world and, especially, among people who benefit from these resources; here we shall refer to small-scale fishing operators.

Small-scale fishing has to tackle many problems: the conflict with illegal trawl-net fishing, the impoverishment of resources and the random nature of the activity itself. For several years, furthermore, so-called "amateur" fishermen, whose numbers have been increasing steadily without regulation or control, have been seriously endangering the very existence of artisanal activities linked to small-scale fishing. This is a result of the increased pressure on the marine fauna, often with devices of illegal length and mesh size, and because of unfair competition since the "amateurs" sell their product on the market without controls. Controls over these illegal activities should thus be increased to allow people who earn their living in this way to work. Several means are possible: the most important undoubtedly include the protection of coastal bottoms from illegal trawl-net fishing, and active repopulation with artificial reefs (BOMBACE, 1981; 1982). Another need, which the fishing world has been aware of for some years, is to eliminate obsolete units (20 - 30 years old) from the fishing fleet. In 1982 these represented about 30% of the total (BAZIGOS *et al.*, 1984): many of these units, most of which are laid up and half-sunk, clutter Italian ports. If these two necessities, protection of the coastline and clearing out of wrecks from ports, are associated, a possibility emerges: sink most of these wrecks in areas which are suitable, from the geological and biological points of view, to form protected oases (LEVI and ANDREOLI, 1989), the management of which can be entrusted to cooperatives or associations of fishermen who pursue on small-scale fishing.

Starting from this presupposition, the Istituto di Tecnologia della Pesca e del Pescato del Consiglio Nazionale delle Ricerche began, in May 1989, a research campaign intended to gain knowledge of the biological resources of an area about 2 ml. SE of Cape Granitola, near Mazara del Vallo (TP) (see Fig. 1). An agreement made with the Harbour Master will allow the sinking in the area mentioned above of some laid-up fishing boats which are now lying along the quays. In parallel an enquiry will be carried out on shipping equipped for smale-scale fishing to discover the entity, the problems, the fishing grounds and the species which are most requested on the market. There should also be a campaign of bionomic studies on the benthic populations.

The aim of this work is above all to inform the scientific community of the initiative we have taken and to confirm the possibility, if not the need, of proceeding with this type of action along the coasts on a larger scale. In this paper we give the first data from the trammel-net fishing campaign.

METHODS

The fishing enquires were carried out using a trammel-net about 700 metres long and 1.5 metres high, constructed "ad hoc". Starting from May 1989 catches were effected every fortnight in a station about 25 - 28 metres deep, on a Posidonia oceanica meadow mixed with rocks, very close to the site chosen for the positioning of the wrecks. Some tests were carried out on the sandy bottoms where the fishing boats will be sunk. The net was cast in the late evening and weighed the following morning staying in place for an average of about 12 - 14 hours: there was also a test catch during the day. In the laboratory we determined the morphological and biological parameters normally used in studies of demersal populations; also the stomach contents of all the fish species caught were sampled.

PRELIMINARY RESULTS

The data collected are obviously only partial as yet, because they refer to the first part of a research programme which is still being carried out; at the moment we have collected (in 13 samplings) 47 species subdivided as follows (see Tab. 1 and Fig. 2): 37 species of teleostians, 3 selachians, 4 cephalopods and 3 crustaceans. The total catch so far is 57,992 grams with an average of 4,461 grams per haul. The predominant species of fish, both in number and weight, belong to the Scorpenidae (Scorpaena notata, S. porcus and S. scrofa) which together represent 23.9% of the total weight and to the Sparidae with 26.1% (Diplodus annularis, D. vulgaris and Sarpa salpa, in particular). There were also some Labridae and Mullidae (Mullus surmuletus). The most important of the Cephalopoda (9.8%) was Sepia officinalis, both in number and in weight, while of the Decapoda Crustacea (7.8% of the total) there was an encouraging presence of Palinurus elephas, which leads us to hope that this species, which is so appreciated on the market, may colonize the wrecks (Fig. 3).

DISCUSSION

There exist relatively few data on experimental research on Mediterranean small-scale fishing, particularly fishing with trammel nets, both concerning data collection methods and zones studied and concerning the composition and quantity of catches, and the data available cannot really be compared. For the Sicilian coasts we can cite the works of BOMBACE (1972), ANDALORO

and CAVALLARO (1982), ARCULEO and RIGGIO (1985; 1989), ARCULEO et al., (in the present report). In other Mediterranean areas we have the works of MOROVIC (1965), ARDIZZONE and BOMBACE (1972) and JARDAS (1985). More data are available on composition, devices used and estimated catches for Mediterranean fishing, although they are still quite insufficient; on this subject, for istance, one may refer to the Proceedings of the Technical Consultation on Approach Methods to Small-scale Fisheries in the Western Mediterranean held at Sète in May 1986.

PRELIMINARY CONCLUSIONS AND PROSPECTS

The research is only beginning and thus here we can only give some very partial and preliminary considerations. A quick look at the list of species and the percentage composition of the catches shows a majority of species of commercial interest which have their habitat in the feeding grounds of Posidonia oceanica and/or on the rock: besides, as fishermen well know, the best fishing grounds are the so-called "mixed rocky seabeds - Posidonia - sand", which offer very varied and stratified ecological niches, because of the great morphological variety of the substrates. We thus find good catches particularly of sparids, scorpenids and mullids: there are also common spiny lobsters and european lobsters, although their preferred habitat is in deeper waters, on coralligenous grounds.

A characteristic of this area, and more in generally of the south-west Sicilian coastal strip, is the high productivity of the waters, probably due to upwelling phenomena caused by the dominant winds and by the currents, which are very strong in this area. The high productivity of the waters is not however used to the full because of the rarity of hard substrata which, particularly from Cape Granitola towards the East, are almost only found on shoals which, precisely for this reason, are very rich. Therefore it is possible that artificial structures submerged in these waters, of whatever shape and material they are built, might not only protect the seabed and attract marine fauna (tygmotropism), but also could lead to a real increase in the biomass, thanks to the greater availability of surfaces for eggs and larvae of benthic organisms. In our case closeness to a wide Posidonia oceanica meadow could help the recruiting action by organisms linked to this ecosystem, offering them possible hiding places and food (RAGONESE et al., 1989). Once the wrecks have been dropped, the study will be mainly oriented to understanding the trophic mechanisms which link the organisms of the artificial reef, especially examining the benthic communities which settle there, thus comparing composition of the stomach contents of some interesting species from both the ecological and the commercial point of view, with the species found in the bionomic samplings. Finally the results will be correlated with the data from similar enquiries which will continue to be carried out in parallel on the adjacent seagrass beds (BELL and HARMELIN-VIVIEN, 1982; 1983), so that we can construct an ecological trophic network model for artificial substrates in south-western

Sicilian waters.

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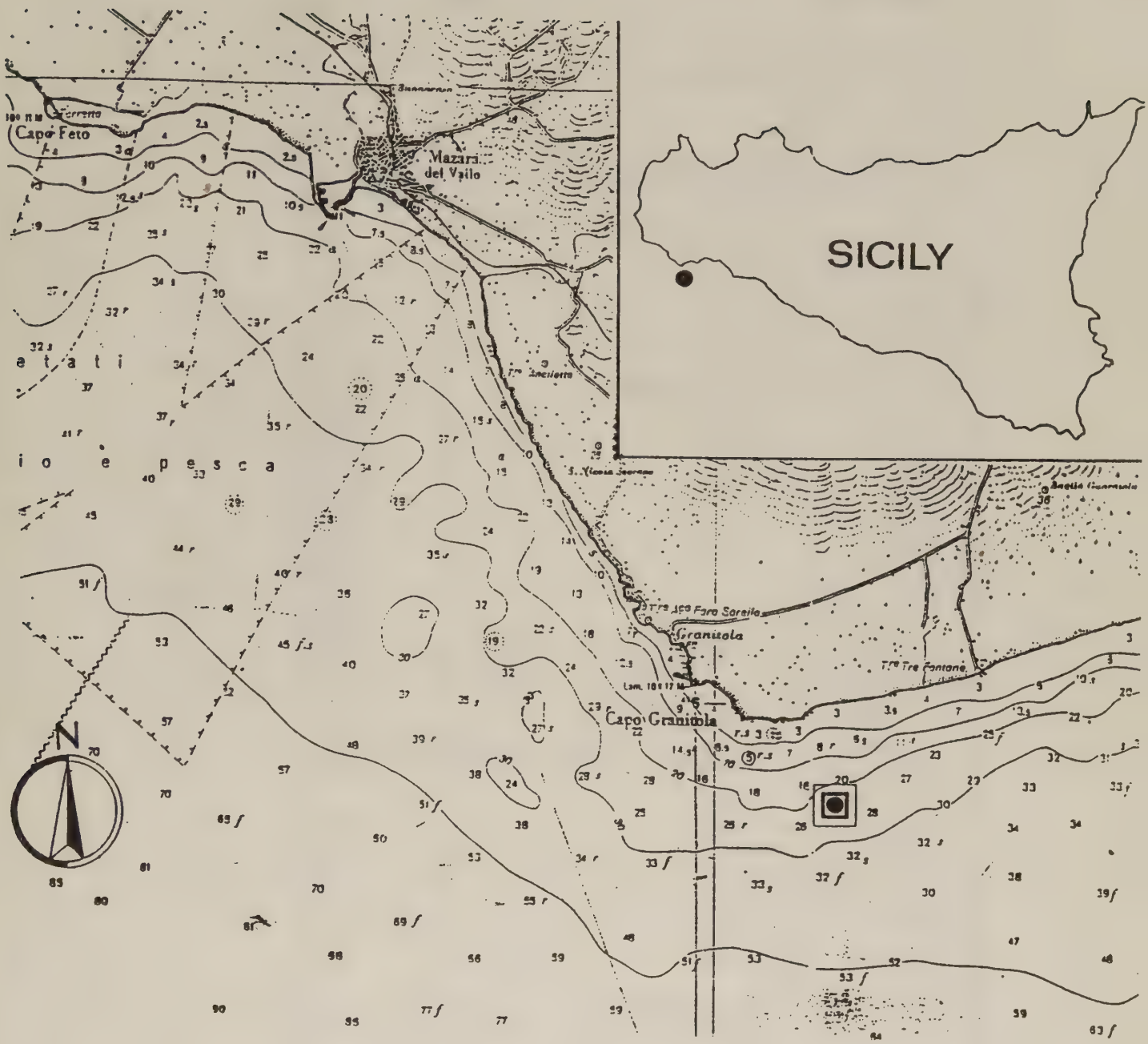

Fig. 1 - Site of wrecks sinking, and fishing survey.

	SPECIES	N° IND.	W. (g)
1	Apogon imberbis	1	16
2	Aspitrigla obscura	1	56
3	Boops boops	29	2146
4	Bothus podas	6	207
5	Conger conger	1	1074
6	Coris julis	2	57
7	Dentex dentex	1	64
8	Diplodus annularis	89	4682
9	Diplodus vulgaris	35	1794
10	Eledone moschata	2	494
11	Homarus gammarus	1	1220
12	Labrus viridis	16	2120
13	Loligo vulgaris	3	954
14	Lithognathus mormyrus	2	153
15	Mullus surmuletus	53	4429
16	Octopus vulgaris	1	528
17	Pagellus acarne	15	1072
18	Pagellus bogavereo	1	72
19	Pagellus erythrinus	8	905
20	Palinurus elephas	12	3279
21	Phycis phycis	11	1720
22	Raja asterias	1	62
23	Raja radula	2	1158
24	Sardina pilchardus	4	126
25	Sarpa salpa	8	3569
26	Sciaena umbra	1	410
27	Scorpaena notata	109	4547
28	Scorpaena porcus	56	6095
29	Scorpaena scrofa	18	3202
30	Scyllarus arctus	2	34
31	Sepia officinalis	19	3698
32	Serranus cabrilla	12	386
33	Serranus scriba	14	830
34	Solea variegata	1	24
35	Solea vulgaris	6	334
36	Spicara flexuosa	3	135
37	Spicara maena	5	252
38	Spondyliosoma cantharus	12	691
39	Symphodus cinereus	1	39
40	Symphodus doderleinii	3	299
41	Symphodus mediterraneus	9	337
42	Symphodus scina	1	85
43	Symphodus tinca	29	3033
44	Torpedo marmorata	1	366
45	Trachinus draco	2	85
46	Trachurus mediterraneus	8	1090
47	Trigla lucerna	2	63
	TOTAL	619	57992

Table 1 - Preliminary list of species.

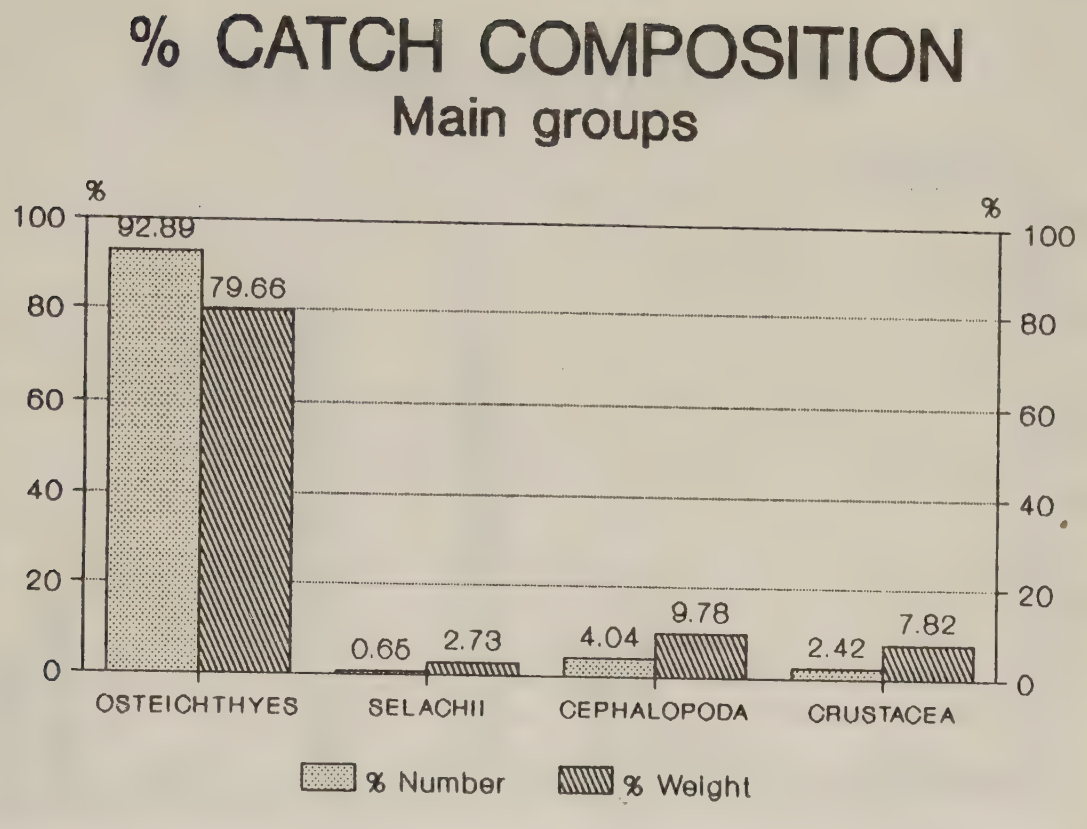

Fig. 2 - Percent in weight and number for main divisions.

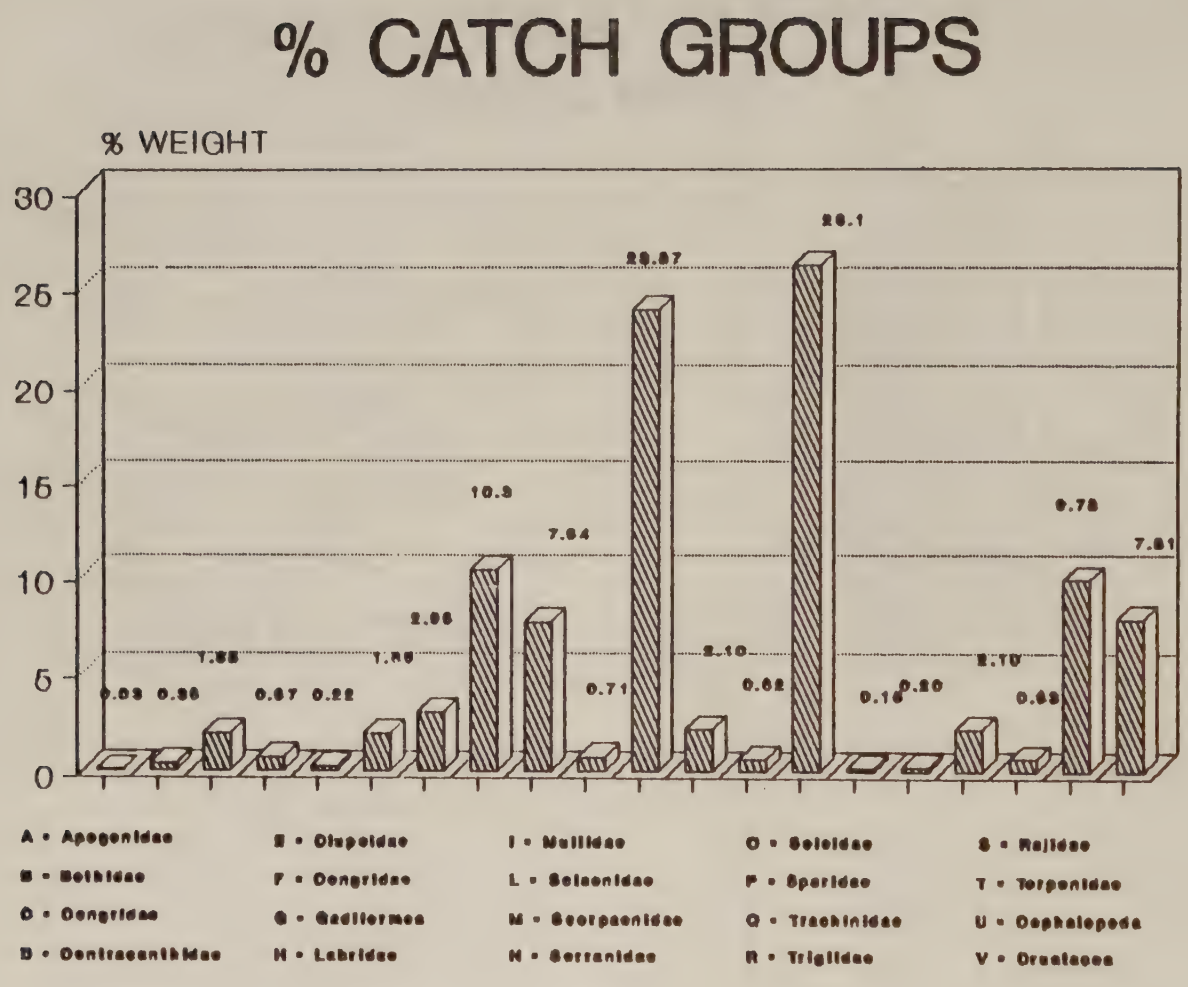

Fig. 3 - Percent in weight for systematic groups.

% CATCH GROUPS

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